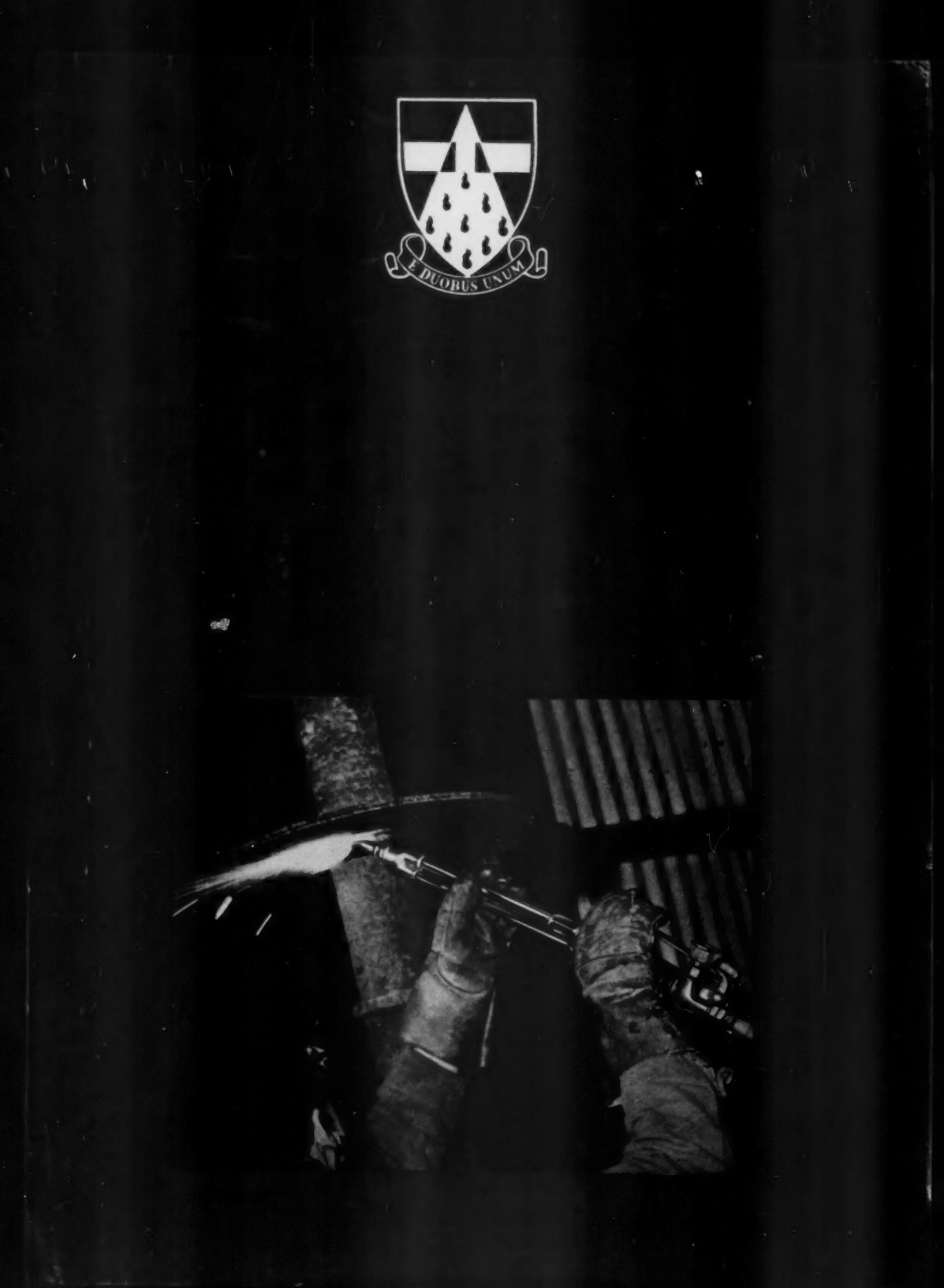
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Civil Engineer-in-Chief, Admiralty,

Mr. G. H. Fretwell, C.B., M.I.C.E.,
Director-General of Works, Air Ministry.

Major-General L. D. Grand, C.B., C.I.E., C.B.E.,
Director of Fortifications and Works, War Office.

Among the recommendations in this report, which represent the joint views of the Ministry of Works, the Admiralty, the Air Ministry and the War Office, are the following:

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IN ASSOCIATION WITH

THE JOINT COMMITTEE ON MATERIALS AND THEIR TESTING

SYMPOSIUM

ON

NOTCH BAR TESTING

AND ITS RELATION TO

WELDED CONSTRUCTION

CONTENTS

NOTCH BAR TESTING AND THE SELECTION OF STEEL FOR WELDED CONSTRUCTION, by W. BARR, A.R.T.C., M.INST.W., F.I.M., and I. M. MACKENZIE, B.SC.

THE ASSESSMENT OF NOTCH DUCTILITY BY A VARIETY OF NOTCH TESTS, by G. M. BOYD, M.I.N.A., A.M.I.STRUCT.E., M.INST.W.

THE STATE OF STRESS AND BRITTLE FRACTURE, by Prof. ING. W. SOETE.

NOTCH BAR TESTS IN RELATION TO SERVICE PERFORMANCE, by C. F. TIPPER, M.A., SC.D.

DEVELOPMENT OF A TESTING-METHOD ON BRITTLE FRACTURE OF MILD STEEL PLATES, by Dr. J. H. VAN DER VEEN.

Report of the Discussion of the foregoing Papers, including contributions by the Chairman (Professor E. C. ROLLASON), the Rapporteur (Dr. N. P. ALLEN), C. E. SHERWIN, T. DENNISON, Dr. A. J. P. TUCKER, Dr. J. H. PATERSON, W. E. BARDGETT, A. H. GOODGER, L. E. BENSON, R. F. BISHOP, Dr. J. A. HARINGX, Civ. ing. NILS G. LEIDE, T. S. ROBERTSON, P. JUBB, J. G. TWEEDDALE.

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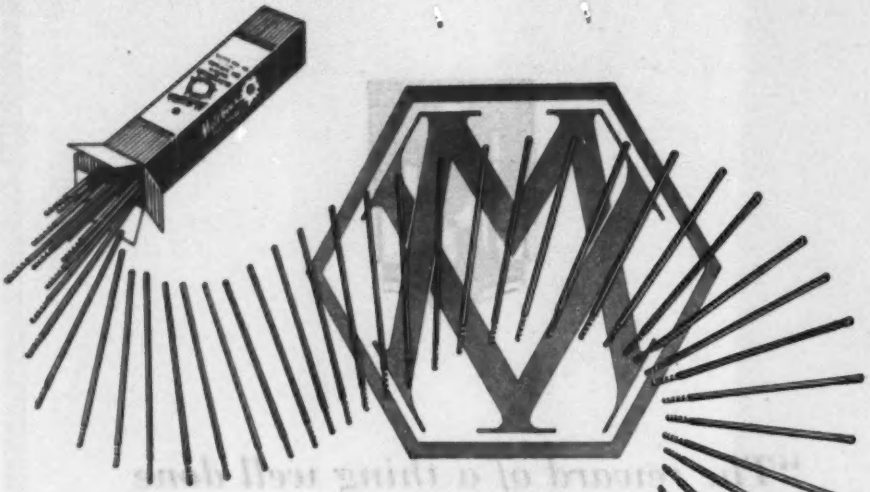

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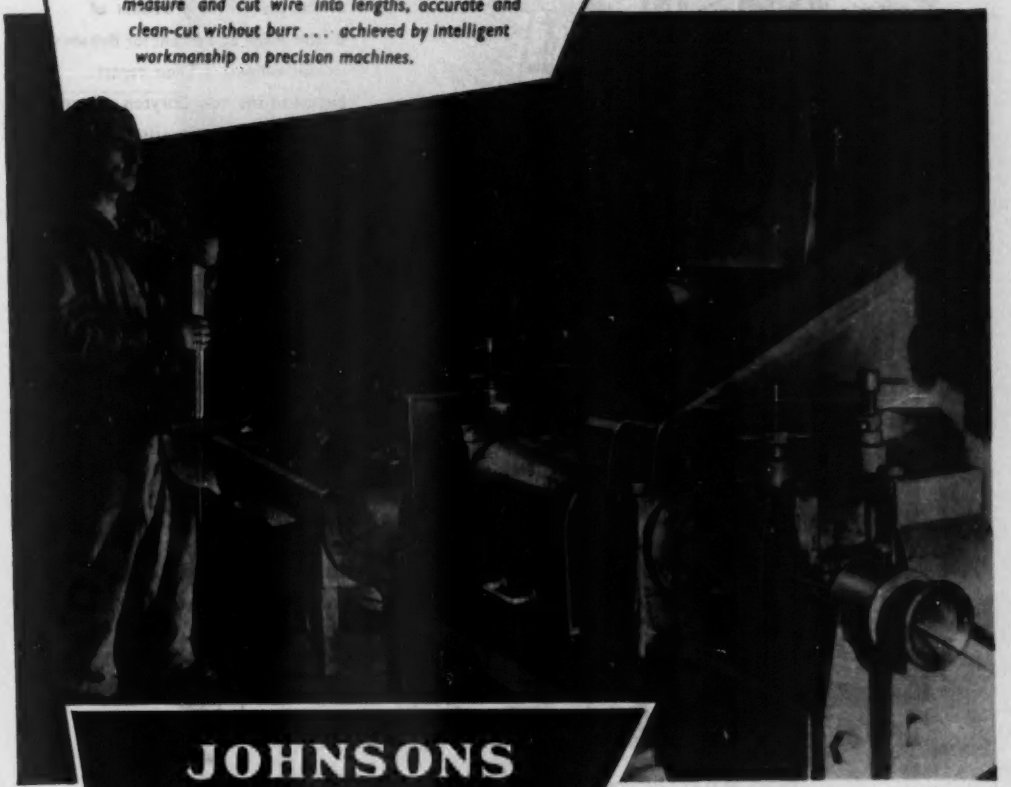

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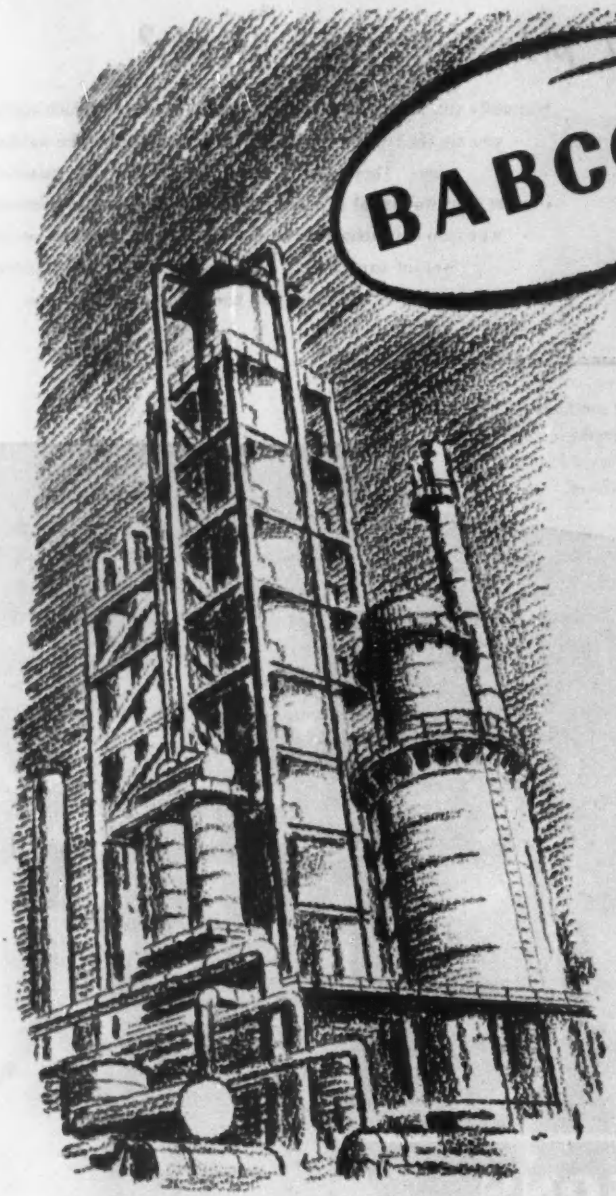

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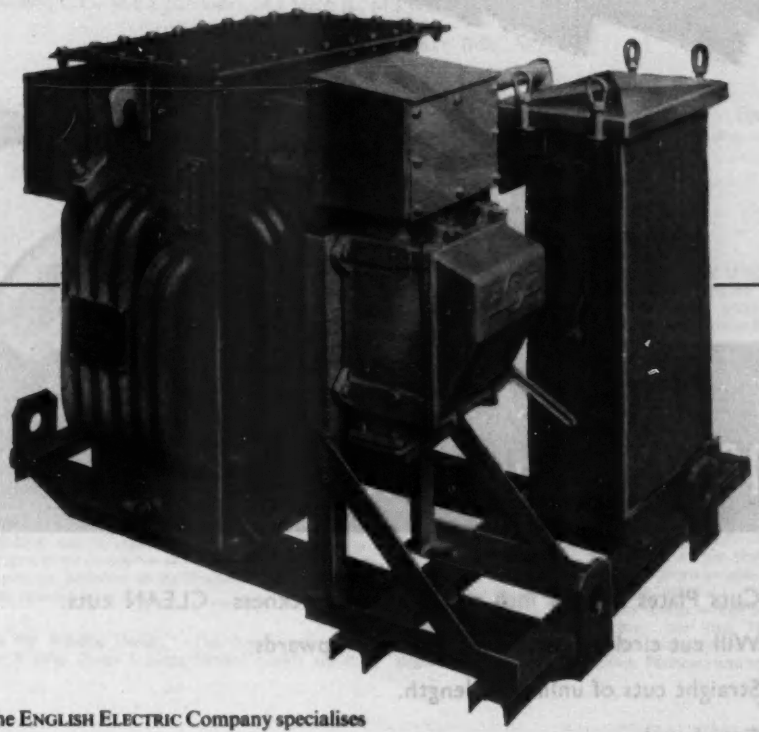

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INSTITUTE NOTES AND NEWS

Welding Periodicals.—Nearly 150 periodicals are regularly received at the Library of the Institute, where they are available for lending to members. The list, a copy of which will be sent by the Librarian to any member on request, includes every journal, in whatever language, dealing exclusively with welding and nearly all the journals in which welding papers appear frequently. Even if the journal you want does not appear in the list, the Librarian can usually obtain a loan for you from another library. Members wanting to borrow a welding periodical should always start by writing to the Librarian of the Institute.

Notch Bar Testing Symposium.—The proceedings of the Symposium on Notch Bar Testing and its Relation to Welded Construction, which was held in December, 1951, by the Institute and the Joint Committee on Materials and their Testing, is now nearing publication and is expected to be issued in January. Attention is drawn to the prospectus of the book enclosed with this issue of *Transactions*. Members of the Institute will be privileged to buy it at the reduced price of £1.

"Handbook for Welding Design."—The compilation of the *Handbook for Welding Design* is going forward quickly and it is expected that all the sections, on which some 15 Sub-Committees are working at present, will be received before the beginning of April. The main Committee, in a report which was adopted by Council in November, has set out a revised plan for the *Handbook*, involving its publication in three volumes. The first of these will probably be published during 1953, or early in 1954, and the other two will follow at short intervals.

Offers of Papers.—Members of the Institute who are willing to read papers at meetings of the Institute or of its Branches are invited to send particulars to the Secretary for submission to the Programme and Journal Committee not later than 21 March next. Where the complete text of the paper is not available, a short synopsis should be sent.

"Handbook for Welded Structural Steelwork."—The Committee which has charge of the new edition of the Handbook invites those who wish to propose changes, improvements and additions, to send them to the Secretary of the Institute.

In the meantime, copies of the fourth revised edition are still available, price 10s. 6d. per copy, post free. This edition incorporates a number of important corrections to the formulae on pages 111-118 of the fourth edition. Members who have the original

FRONT COVER ILLUSTRATION.—For gouging in the overhead position, the B.O.C. Cutogen 5 is the perfect tool. Equipped with 75° or straight heads, the Cutogen 5 makes quick, neat work of removing below-standard welds (as shown in the illustration). As a speedier alternative to mechanical chipping, it is widely used in shipbuilding and other constructional work in which a single rejection can involve serious losses in time and labour costs.

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PRINCIPAL CONTENTS

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fourth edition are invited to apply to the Secretary for copies of the corrected pages, which will be supplied post free.

List of Films.—The first edition of the Institute's list of welding films has been exhausted and a new edition, incorporating several additional films, is now available, price 1s. 6d. (to non-members 2s. 6d.). The list contains the exhibition details and brief synopses of 81 films, which are classified under thirteen subject headings. A simple reference system enables one to find the name and address of the suppliers of each film.

Appointments Register.—Industrial Corporate Members may like to be reminded that a register of members seeking posts as foremen, supervisors, representatives, managers, designers, etc., is maintained at the offices of the Institute.

Employers seeking staff (other than welders) are cordially invited to inform the Secretary of the Institute of their requirements, and so assist the Institute to expand this valuable service to its members.

Prize for Mr. G. G. Musted.—We congratulate our member, Mr. George Gordon Musted, on winning the third prize in the 1952 International Prize Competition conducted by Eutectic Welding Alloys Corporation of Flushing, New York. Mr. Musted's contribution was entitled "Improved Technique for Training Welders with Low-Melt Filler." We understand that this is the third international prize won by Mr. Musted.

University Lectures.—We are glad to note that Mr. S. M. Reisser, a member of the Council, has given two public lectures on arc welding and its economic use in structures and machines at the University of London, King's College, Faculty of Engineering.

Binding of Transactions.—Arrangements have been made for the binding of members' volumes of *Transactions* in black embossed leathercloth at a cost of 10s. 6d. each, plus 1s. for postage and packing. Members wishing to take advantage of this arrangement should forward parts, with index, to Mansell (Bookbinders) Ltd., 41, Britannia Row, Essex Road, London, N.1.

Correction.—We much regret that the initials J. F. L. were attached to the review of the Copper Development Association's book, *The Welding, Brazing and Soldering of Copper and its Alloys*, on page 98 of our August issue. The initials which should have been attached are E. D., and we apologise to both gentlemen concerned.

Welding Abstracts.—The International Institute of Welding publishes a quarterly abstracts journal, entitled *Bibliographical Bulletin for Welding and Allied Processes*. This contains abstracts, printed both in English and French, of papers and books on welding subjects published in all parts of the world. It is arranged under subject headings, so that the whole of the current work on any given aspect of welding can be reviewed in a few minutes. The Annual Subscription for members of the Institute of Welding is £3 5s. 0d., and orders may be placed with the Secretary of the Institute at 2, Buckingham Palace Gardens, London, S.W.1.

American Welding Society.—The new Officers of the American Welding Society are as follows: *President*, Mr. Fred. L. Plummer, Director of Engineering, Hammond Iron Works, Warren, Pa.; *First Vice-President*, Mr. Eric R. Seabloom; *Vice-President*, Mr. J. H. Humberstone.

Kingston Technical College.—Announcing an advanced welding course for those engaged in industry who require to extend their knowledge so as to be able to introduce new methods into manufacturing processes, the engineering department of the Kingston-upon-Thames Technical College recently drew attention to the new welding equipment installed there, particularly for resistance welding. The college has a spot welding forge, a universal seam welding machine with electronic timing unit, a projection welding machine also with an electronic timing unit, an automatic flash butt welding machine and an atomic hydrogen welding machine. Equipment of this kind is so rare in technical colleges that one speaker at a recent Institute meeting went so far as to say that there was no college in which a student could obtain training in resistance welding. It would be interesting to know whether any other college in the country has equipment comparable with that at Kingston-upon-Thames.

BOOK REVIEW—

Practical Radiography for Industry. By H. R. Clauser. Reinhold Publishing Corporation, New York. Pp. 301. 60/-.

The treatment in this book of the subject of radiographic testing and inspection is essentially practical, although sufficient explanatory detail in simple terms is given to make it invaluable both to the practical worker in industry and the student.

The advantages and limitations of the radiographic process are discussed, and the nature, characteristics and properties of X-rays are described in sufficient detail to provide the practical operator with information directly applicable to the task of radiographic inspection.

A comprehensive description of the X-ray equipment and guidance on the choice of X-ray generating equipment for any particular application are given.

Of special interest to the operator is the chapter on procedure, exposure factors and technique, films and film processing receive attention; film blemishes and their cause are well illustrated and explained.

Gamma-Ray radiography is described in a separate chapter, in which the emphasis is on radium and radon; cobalt 60 is mentioned, but iridium 192 is not mentioned at all, which pinpoints the difference in British and American practice. In Britain greater use is made of the radio-active isotopes than in America and the use of sources such as iridium 192 has resulted in improved technique, particularly in the lighter and thinner materials.

The radiography of castings and fluoroscopic methods are described, but of particular interest to welding personnel is the comprehensive chapter on the radiography of welds, in which set up, procedure, technique and identification of weld defects, such as cracks, incomplete penetration, lack of fusion, porosity and slag inclusions, are described.

In the description of specifications and standards, the disparity between American and British practice is again apparent. The American standards lay down definite requirements for judging the soundness of fusion welds, and although they are arbitrarily chosen, they are acceptable to the various authorities concerned, this being in complete contrast to the British practice in which the radiograph is assessed for the particular service condition to which the weld will be subjected.

The radiography of spot welds is covered and well illustrated, the various types of defects that can be identified being described.

High voltage radiography using X-rays generated by one million volts and higher is described, with particulars of the characteristics of high voltage X-rays, such as sensitivity, secondary radiation, definition, latitude and application. The special equipment, technique and procedure for the generation of high voltage X-rays are described in some detail.

A final chapter deals with a very important feature of radiography, namely protection and safety of operating personnel; here the value of protective materials is explained as well as the usual medical precautions that should be taken.

This is a book which, as its title suggests, is primarily directed to those who are actually performing radiographic inspection, although there is sufficient detail given of the fundamental principles to make it useful to the beginner or the student. The subject is dealt with in a concise, relatively non-technical manner and the result is an excellent and valuable contribution to the available literature on the subject.

S. H. G.

THE PRESIDENTIAL ADDRESS

Mr. ROBERT JENKINS ON THE CONTROL OF DISTORTION

WE people who are daily concerned with the use and application of electric arc welding have many problems, but perhaps the greatest are those of residual stresses and distortion.

Comparatively little has been written on the subject of distortion, though one or two papers have been given in this country, on the Continent and in the U.S.A.

Perhaps one of the best works is by Guyot, a Belgian (Guyot, 1946), but our own R. G. Braithwaite has done very useful work, which incidentally won him the Larke Medal in 1949 (Braithwaite, 1950). A. E. Berriman in 1941 and D. M. Kerr in 1950 wrote on distortion in structures and shipbuilding respectively (Berriman, 1941; Kerr, 1950). Beyond these, there would appear to be little of real practical value on this side of the Atlantic.

I am going to give some results which have been obtained by shop experiments but which do not agree entirely with Guyot, nor with Holt of the U.S.A. (Holt, 1947).

One of the main reasons why the work on distortion is limited must be because the many variables encountered in shop practice and technique, which can give rise to very mixed results and opinions, make it extraordinarily difficult to arrive at a common basis for fixing reliable rules on which to work.

Some of the variables with which we have to contend are:

(1) Type of material and thickness.
(2) Method of preparation of plate edges.
(3) Design of the job to be welded.
(4) Amount of restraint, e.g. are plates being welded free to move, or are they held rigid by the design and construction?
(5) Accuracy of set up.
(6) Type and make of electrode.
(7) Size of electrode and current.
(8) Rate of deposition.
(9) Number of runs.
(10) Manual or automatic welding.

Distortion is produced by shrinkage, and every one of the foregoing conditions can affect the amount of shrinkage. Shrinkage is the residual contraction in volume of a piece of metal after cooling from a high temperature, and distortion results when the temperature distribution is not uniform. The local heating to a high temperature produced by the arc welding operation means that the temperature distribution is non-uniform.

During welding, the hot metal tries to expand but is prevented to a great extent from doing so by the surrounding cold metal, hence producing permanent compression; therefore, the area under compression, when cooled, contracts and becomes shorter than the surrounding cooler areas, thus producing shrinkage or permanent shortening.

The foregoing is proved by the practical method of removing buckles from a plate by heating localised spots by an oxy-acetylene torch. The heated part, during its expansion, undergoes compression, due to the restraint put upon it by the neighbouring cooler parts. This results in the shortening, or shrinking of the heated part during cooling, thereby removing the buckle, or bump.

Measurement of Distortion

I propose to give you the results of tests made in the shops, to indicate some idea of transverse and longitudinal shrinkage, and then to show some of the practical applications of methods of *reducing* distortion; after that, we shall see how to cure distortion and straighten a job by the local application of heat, followed by examples of staying and strutting to control distortion. Lastly will come descriptions of how certain welded vessels have been made usable after severe treatment has, to all intents and purposes, destroyed them.

Fig. 1 shows various results obtained by welding a $\frac{1}{2}$ in. thick plate manually with a single V preparation, plotting the longitudinal distortion in one hundredths of an inch in relation to the number of runs. You will see that various types of electrode have been used with mixed results. The welding conditions were kept as constant as possible. All these test plates had a preparation of a 60 deg. included angle and all had a preliminary backing run of an 8-gauge class E217 electrode at 170 amps. For the main runs, the current was kept constant in relation to the size of electrode, e.g. 10 gauge—125 amps.; 8 gauge—170 amps.; 3/16 in.—210 amps.

The method by which the distortion was measured is shown in Fig. 2 which, illustrating a "clock" used to register the longitudinal movement and a long pointer, arranged on a scale, to enable the transverse movement to be registered in degrees.

You will notice that with 10 gauge electrodes used on the multi-run principle, the longitudinal distortion reaches a maximum

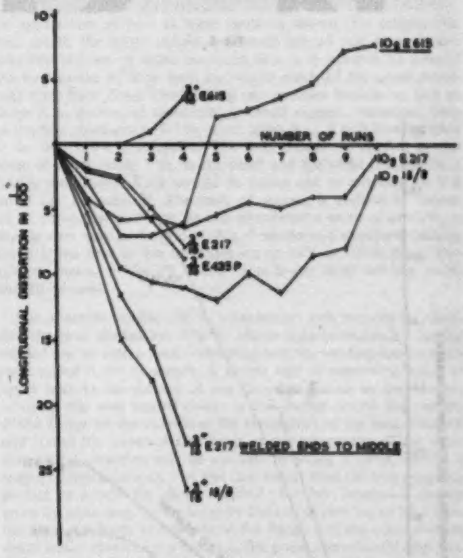

Fig. 1

after three or four runs, and as we approach the eighth, ninth and tenth runs, gradually corrects itself until there is very little to show at the end of the last run. For some reason, the two test plates made with 10 gauge and 3/16 in. electrodes of the E615 class seem to have gone quite contrarily to the rest of the work. I can offer no reasonable explanation of this, all the conditions having been kept constant.

It is rather curious to note that the bigger electrodes and higher currents definitely produce a greater degree of longitudinal distortion, and particularly in the example shown here, which is welded from the ends to the middle, a practice which some people have recommended for reducing this distortion. The worst example shown on this line is in stainless steel, welded with an 18/8 elec-

trode. The reason for this is the greater coefficient of expansion of stainless steel.

Transverse Distortion

In Fig. 3 we have the graph of the number of runs against transverse distortion in a ½ in. plate, manually welded with a single V preparation; in other words, the same conditions as shown on Fig. 1, but for transverse instead of longitudinal distortion. This seems to be somewhat at variance with the results shown in Fig. 1, in that the small electrode with a greater number of runs produces a greater degree of transverse distortion than the larger electrode put down with high current at much greater speed. There is little doubt, however, that in welding up fabricated constructions, the transverse distortion is a much greater cause of trouble than the longitudinal distortion. I think it is also true to say that, from a practical point of view, we get less trouble from distortion in welding up a job with the minimum number of runs with the maximum speed and rate of deposit.

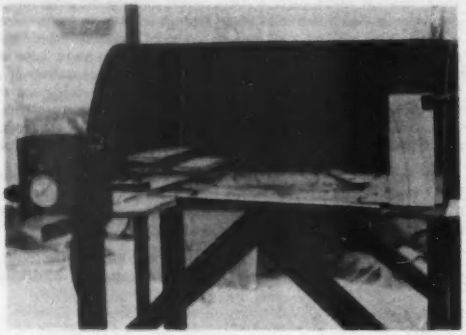

Fig. 2

Fig. 4 relates to similar tests on 1½ in. thick plate, manually welded, and shows the transverse distortion in degrees in relation to the number of runs. You will see that two types of preparation have been used, the U and the double V; the graph clearly indicates that the degree of distortion is minimised by using fewer runs and larger electrodes with higher current values, the degree of distortion by this method being approximately half that produced by using an 8 gauge electrode and practically double the number of runs.

To illustrate the principle that the greater or the heavier the run, the less the distortion, a 1½ in. plate was welded by the Unionmelt process, the double V preparation being Unionmelt welded on both sides. The smaller backing run was put in first and produced only half a degree of variation after the one run. The main, or major run, was put in from the top side, and there was no change in the amount of distortion, leaving the finished plate with only half a degree of transverse distortion. The first run was put in with an arc voltage of 35, current 1200 amps., and welding speed of 12 in. a minute. The main run was put in with an arc voltage of 38, current 1500 amps., and a welding speed of 10 in. a minute. A similar plate of 1½ in. thick was welded by the Unionmelt process with a hand-welded backing run, the preparation for the backing run being of the U type and the plate preparation for the Unionmelt run of the V type. The backing run consisted of six runs, being one run of 6 gauge at a current of 220 amps. and five runs of ¼ in. electrode at 320 amps. This produced a transverse distortion of 4½ deg. after the hand welding. The Unionmelt side was then welded with a single run of 37 arc volts, 1800 amps. and a welding speed of 7½ in. a minute, and this resulted in a transverse movement of the plate of 3½ deg., leaving a mean angle of distortion of 1 deg. in the direction of the hand-welded side.

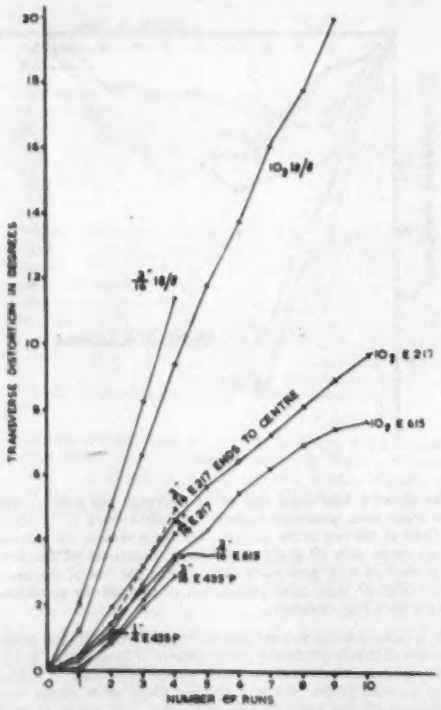

Fig. 3

Allowances

Arising out of the obvious fact that steel distorts as a result of being arc welded, most people take various necessary steps to combat this. The number of variables already given indicates

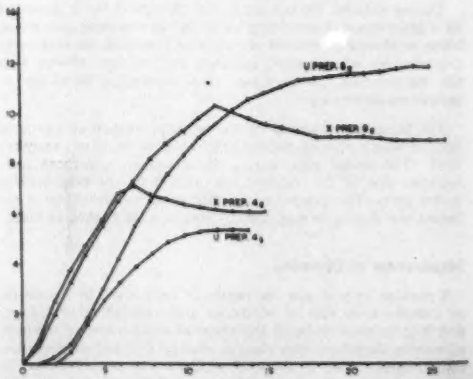

Fig. 4

the difficulty of laying down hard and fast rules. In spite of this, however, some effort must be made to make initial allowances during the preparation of plates. It must be obvious that if drawing dimensions are to be worked to and even the widest of tolerances complied with, some allowances must be made. Some suggested allowances are given here, based on practical experience:

On large rectangular tanks with heavy bar flanges for the tops, 3/16 in. is added to the drawing dimension of the widths and breadth, plus ¼ in. in depth or height.

On smaller rectangular tanks, an allowance of plus ⅛ in. is made on inside dimensions and plus ¼ in. in height, this latter being extended to 3/16 in. if there are many stiffeners or fittings welded on to the walls.

For cylinders with several strakes, an allowance of plus 1/16 in. is made in length of each strake—a good idea is to make the standard allowance on one strake, then weld and measure this, thereby arriving at a reliable allowance for the rest.

Types of work differ, so that it is really only possible for firms to establish their own standard of allowances to suit their own particular methods and designs. A factor which must not be forgotten and which is nothing to do with weld shrinkage, is that allowance must be made for the stretching of the material during manipulation. In the thicker plate sizes this far outweighs allowances made for shrinkage.

In addition to such allowances, there are other steps which may be taken to control or minimise distortion. One method is

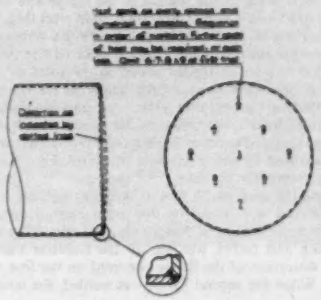

Fig. 5

to balance, as far as possible, the contractional stresses by working out a careful sequence of welding designed to balance or neutralise the contractional stresses.

Another means of minimising distortion is to make sure that the standard of preparation is absolutely faultless. The fit up of the plates should be good and accurate, since, obviously, if large gaps are left in the joints, unnecessary heat and an undue volume of weld metal will have to be deposited in order to bridge these, producing further possibilities of distortion.

Figs. 1, 3 and 4 indicate that, wherever possible, use should be made of the larger electrode with a high current and reduced welding time. In other words, the reduction to a minimum of the time in which the steel is subjected to heat reduces the area of plate affected, and so helps to minimise the amount of distortion.

The cause of distortion in a welded structure is the local application of heat. Therefore, as explained earlier, local application of heat is one of the means of correcting weld distortion. I propose, therefore, to give you two or three other examples in diagrammatic form, showing how this is done in shop practice, and to follow up with some photographs of work in progress.

Correction by Local Heating

The first example (Fig. 5) shows a simple cylindrical vessel with a flat welded end or bottom plate, which may be in any thickness of plate usually encountered in what we call the light or medium tank work field. The weld is a corner weld inside and out round the periphery of the cylinder, which produces contractional stresses round the periphery of the flat end plate, thus causing a bulge in the centre. This condition can easily be corrected

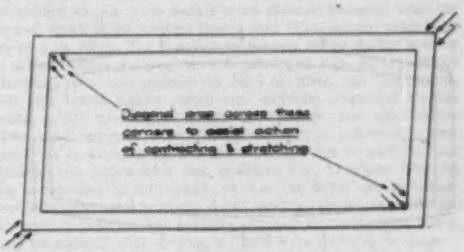

Fig. 6

by application of heat in local spots as shown. To achieve the best result, the spots should be evenly spaced and symmetrical over the bottom. It must be noted that it is possible to overdo the application of local heat and undo much of the good which may have been done. Overheating can produce buckles as bad as those it is desired to eliminate. I would suggest, therefore, that in the first place, spots 1-5 be tried, spots 6, 7, 8 and 9 being tried if the first prove inadequate. The heat should be applied in the form of spots about 2 in. in diameter and the plate brought to a cherry red colour. Care should be taken not to overheat or the effect can be nullified. The heat, of course, is applied by means of an oxy-acetylene flame. In this connexion a word or two about nozzle sizes may be helpful. A No. 9 nozzle in a standard welding torch is the best to use for anything up to ½ in. thick plate. For thicker plates, a No. 23 nozzle in a heavy duty welding torch should be used.

Considerable trouble can be experienced with rectangular tanks and the next illustration (Fig. 6) shows diagrammatically the top welded bar on such a tank, indicating how the welding contractions have pulled it out of square. A simple way of correcting this is to apply heat to the corners of the flange as shown by the arrows, bringing the area heated evenly a few inches round the corners of the flange on the outside at the extremities of the long diagonal and round the inside of the flange at the extremities of the short diagonal. Correction can be assisted by using a prop, having a length of approximately ½ in. per foot longer than the true diagonal, pushed in across the short diagonal. Further assistance can be given by stretching the material by the use of two heavy hammers, the one held firmly at one side of the flange and the other striking sharp heavy blows to the flange at the point immediately opposite. The tank must be hit round that corner which is opposite to the side on which the heat has been applied, thus assisting the part to be contracted by stretching the outside.

Now comes another example (Fig. 7) concerning large rectangular tank work, showing how the heavy type flange or curb can be distorted by the weld which joins it to the top of the tank body. Again the cure is comparatively simple: it consists of the local application of heat to the spots indicated by the arrows, and the torch in this case is applied across the face of the flange in a V shape, the wider part of the V being on the full side which is being shrunk. This is particularly necessary if the flange is a heavy one.

Large rectangular tanks with heavy stiffeners can bulge appreciably in the panels made by the positioning of the stiffeners; this

bulging can be eliminated again by heat applied to spots in the middle of the panels as described a little earlier. The sketch (Fig. 8) indicates the manner in which this can be done, and a tank in a comparatively bad state can be brought into good shape, with almost complete flatness in the panels.

Another problem of distortion, which presents itself regularly, occurs when a heavy bar is welded round a cylindrical vessel to form a flange. It is usually found that distortion takes place in flanges which have to be used for making joints for covers on top of vessels. It is possible to avoid a great deal of this distortion by

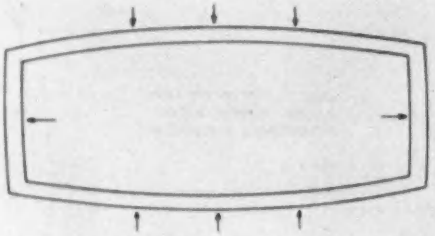

Fig. 7

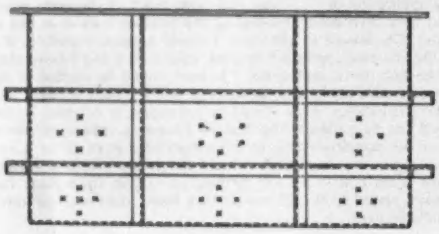

Fig. 8

means of step and sequence welding, but this is not necessarily an economical method and the results indicated by the dotted lines on Fig. 9 show what happens in the majority of cases. The method of correction is simple. Where the flanges are rolled into shape, stresses are set up in the material itself which are partly released by welding, and therefore it is as a rule impossible to predict the reaction of the flanges to the welding operation. Application of heat as indicated in the sketch will do all that is necessary to bring the flanges straight and flat, if care is taken to see that it is applied quickly and that the full thickness is not heated to an appreciable extent, since the skin shrinkage creates the stress or force which flattens the flange.

A typical example of this is illustrated by the results which

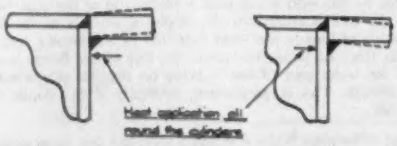

Fig. 9

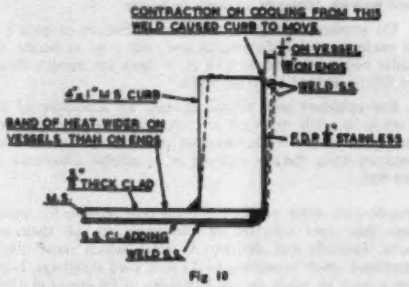

Fig. 10

occurred in a large stainless steel clad cylindrical vessel in which unbalanced welding could not be avoided. The vessel in question was 25 ft. long and 6 ft. 6 in. in diameter and both ends were bolted on by means of heavy flanges. The vessel was constructed from ½ in. thick material with 25 per cent. of stainless steel cladding. Fig. 10 gives a detail of the section of the flange and the welding. The flange itself was a 4 in. × 1 in. thick mild steel ring, which had to be welded round, and in order to provide the stainless cladding condition on the surface of the flange, a piece of ½ in. thick F.D.P. stainless steel had to be welded round in the form of a wrapper. The effect of the main welds of the flange to the body, plus the effect of welding the wrapper plate into position, produced the result indicated by the dotted line on the sketch. This was corrected by working round the vessel with an oxy-acetylene torch in the position indicated by the arrow and so producing a band of heat all the way round. On cooling, the flange came back to its proper position, and the joint which had to be made tight on a ½ in. thick jointing material was made the first time without any difficulty. It should be noted that these flanges were machined flat and square after welding and before welding on the stainless steel wrapper plate. The distortion of the flange occurred on the first which was so treated. When the second flange was welded, the wrapper plate

Fig. 11

was made so that it extended only to the centre of the flange, in other words, to the neutral axis, and was welded in position along that line. This resulted in the remaining flanges being perfectly flat and square after welding without any necessity for correction.

I will now describe the actual effect on some selected vessels.

Some Examples from Practice

The vessel shown in Fig. 11 is made of ¼ in. plate just under 7 ft. long, 3 ft. deep inside and nearly 2 ft. wide. The cover is a flat piece of ¼ in. plate with all the branches which you see, many of them being pipes which go down almost to the bottom of the vessel. This cover is further weakened by the rectangular hole cut into it, 3 ft. 6 in. long × 12 in. wide, and the illustration, which shows a straight edge along the top of the cover after welding

Fig. 12

and cutting the hole, gives the amount of distortion which has to be corrected. It is particularly important in this vessel, since all the flanges of the pipes have to be reasonably parallel so that they will join up to manifolds to be attached to the tank after its completion. Applying heat by means of the oxy-acetylene torch to four V-shaped spots and allowing the vessel to cool naturally, causes the flanges to line up all through, without any other treatment.

Fig. 12 shows a vessel some 2 ft. in diameter, on to which a rectangular plate is welded in order to form a flange, producing distortion on the underside. The operator is applying heat at the corners, in order to pull them into shape. The heat contraction is assisted by pressure from a jack which is shown in position in front of the operator. All the corners were treated in this manner and the flange was brought back to straightness.

The transformer tank shown in Fig. 13 has a very flexible cover made out of ¼ in. plate. The cutting of holes in the cover, and the welding-on of the pocket on the top, caused the plate to distort very considerably. The cover itself, in the flat, is 2 ft. 6 in. × 2 ft. 9 in. The picture shows it bolted down into position on the tank, and the spots between the bolts indicate where heat has been applied; subsequently the cover was allowed to remain in the bolted-down position until it was cold, when it was perfectly flat and straight, after the bolts had all been removed.

Now for a few examples of the means by which shape can be maintained by pre-stressing or restricting the movement of the plate during the welding operation. The first case is that of the two halves of a cylinder, which are designed to be fitted round a cylindrical object to serve the purpose of lifting clamps. It is essential, therefore, that the finished shape should be accurate and circular. The clamps are made of a body plate ½ in. in thickness with two heavy lugs on each half, through which the bolts pass in order to fix them together around the object to be lifted, and six further heavy lugs welded to each half. The two halves have a gap of 1½ in. between them. Obviously, this is a great deal of welding to put on to such a small piece of material, since the overall depth of the finished ring is only 12 in. All the welds have to be ½ in. fillets. The question of keeping shape during welding is solved by tack-welding the main joining-up lugs, through which the bolts pass, into position on the ½ in. plate, and then pulling the two halves tightly round two carefully machined circular plates which are slightly larger in diameter than the finished diameter is required to be. The fixture then, as indicated, is used partly as an erecting jig, and the other six lugs on each half are located and tack-welded into position. Fig. 14 shows how the jig is mounted to turn easily, so that the welds can be carried out in a downhand position. After welding, the whole is allowed to cool in position, being firmly clamped to the circular plates, and on removal after cooling, is found to be perfectly to shape.

Clamping

The next example concerns the half cylinders, one of which is shown in Fig. 12, where it was given to show what happens when welding on a flange of the description shown. In actual fact, distortion is avoided by bolting two of the cylinders together with the flanges face to face, and pulling the corner bolt in tightly with a piece of packing in the centre of each of the square sides.

The weld is then completed in this position, the amount of the packing being regulated so as to produce the desired result first time, the thickness of packing in this case being ½ in.

A further application of the clamping together of two similar objects in order to keep them in shape is shown in Fig. 15. Here are two base plates of a somewhat heavier nature, though still compact. This very compactness makes them stiff and not easy to control. The length is 4 ft., the width overall more than 18 in., and the depth on the flat flanges 8 in. The bottom flange consists

Fig. 13

of two thicknesses of ½ in. plate welded together, giving an overall thickness of ¾ in., and the rest of the construction is made up of ¼ in. and ½ in. thick plate. After tack-welding, the two bases were pulled back to back by means of clamps with a piece of packing in the centre of each of the long flanges. The welding is then completed in this position, and on being allowed to cool before breaking down the clamping, the bulplates are maintained in perfectly straight and flat order. The amount of packing in between the clamped faces is about ½ in.

Similarly, two large transformer tank covers are clamped together for the welding to be carried out completely in both,

Fig. 14

with packing spaced at suitable intervals in between the clamps, so as to allow the flanges and the covers to come down to a good shape on cooling. If the size of the covers is some 10 ft. long by 4 ft. wide, the amount of packing is about 1½ in. in thickness. Many such covers are made and clamped together in this fashion during the welding operation and the result on removing the clamps after cooling is almost perfectly flat covers.

Propping and Staying

The next group of Figures show one or two jobs which can be kept in good shape by careful propping and staying. The first example is a large transformer tank, approximately 16 ft. long × 5 ft. 6 in. wide × 10 ft. 6 in. high; made from ½ in. thick plate. The flange round the top of the tank is 5 in. × 1½ in., and the stiffeners welded round the outside are 7 in. × 3½ in. channel.

Some of these large rectangular transformer tanks are difficult things to keep in shape. Owing to the heavy stiffeners and the many openings and pockets which are welded, a considerable amount of staying and strutting is necessary to prevent distortion.

Fig. 16 shows a tank with the very awkward side pocket, which gives every opportunity for considerable distortion to take place by welding, and indicates how this is stiffened or strutted very strongly in an endeavour to hold it in shape whilst the welding is carried out. These methods have proved very successful and are in daily use.

Another example of a transformer tank appears in Fig. 17. The body is made of ½ in. plate, the top flange is of 2½ in. × ½ in. thick bar, and the body is punched to take 428 elliptical tubes, as well as being considerably weakened by all the various openings which are cut into it; in addition, pockets are welded on. Tanks of this description prove very difficult indeed to keep in good shape during manufacture, and this slide shows how they are stayed and strutted in order to maintain their shape during welding. The size is nearly 8 ft. high to the tank flange, 4 ft. 6 in. wide and 5 ft. 3 in. long.

In Fig. 18, showing the finished job with all the stays and struts removed, all the elliptical tubes welded in, and ready for test, you will observe that there has been, in spite of the careful staying of the openings, some slight distortion, and you can, by careful observation, see where local heat has been applied in order to bring it finally into line and to give it the excellent shape which is indicated in the picture.

The next example can be applied to any fairly heavy cylindrical vessel which has a tube plate (such as a small condenser, heat exchanger or refrigerator unit). When welding the tube plate, which may be about 1½ in. to 2 in. thick, to the main body cylinder, the welding must be carried out from the back, as shown in Fig. 19. The body plate is let into the back of the tube plate which is machined out to take it, this preparation resulting in a heavy weld which contracts on cooling and produces a bellying of the tube plate as indicated by the position of the dotted lines. This can be removed almost entirely by the application of a circle of heat on the face of the tube plate opposite to the weld. This will serve to pull the bellied plate back to its proper position, and if there is still any sign of the bulge after cooling, a few local spots of heat nearer the centre of the tube plate may be necessary to complete the straightening operation.

Whereas this method of straightening has proved adequate, it has been found better to avoid this distortion by pre-dishing of the tube plate, so that on assembly to the body it shows a bulge towards the interior of the vessel. The amount of dishing should be approximately ½ in. per ft. in diameter over 12 in. The example given in the sketch would be dished inwards approximately ¼ in., the diameter obviously being 5 ft.

Straightening after Accidents

I now propose to give you what, in my opinion, are interesting examples of jobs which have run into difficulties in service and have been made good again when returned to the factory. The first of these is a transformer tank which underwent an internal explosion; the straight edge placed down the side shows how the side was bellied out (Fig. 20). The stiffeners are also considerably

Fig. 18

bent! The tank in question is about 6 ft. 6 in. high × 6 ft. 6 in. long × 2 ft. 6 in. wide, made from ¼ in. thick mild steel plate. The horizontal stiffeners are made from 4 in. × 2½ in. × ¼ in. thick mild steel angle welded on the toe to the tank. The vertical stiffeners consist of 4 in. × ¼ in. thick mild steel bar welded to the base channels and the horizontal stiffeners.

On the pocket side there was similar but smaller distortion, but the two end faces, which are shorter and obviously very much stiffer, had not distorted appreciably under the effects of the explosion, and little or no work had to be done on them. Local heat was applied from an oxy-acetylene flame, the positions being

Fig. 16

chalked in (Fig. 21) to indicate to the operator the extent to which the tank should be heated in order to achieve the contractional effect which would result in the straightening movement. Fig. 22 shows local heat being applied to the top flange, whilst at the same time pressure is put on the centre of the flange (which had bellied upwards a little) by means of a jack, which can be seen pushed against one of the stanchions of the building. When the tank went away again, it was exactly as it was when it was new. None of the welds had fractured or parted in any way, and the tank stood a hot oil test perfectly satisfactorily.

Fig. 17

A Collapsed Mixing Vessel

We now come to a rather more difficult job which had to be tackled. It consisted of a stainless steel jacketed mixing vessel,

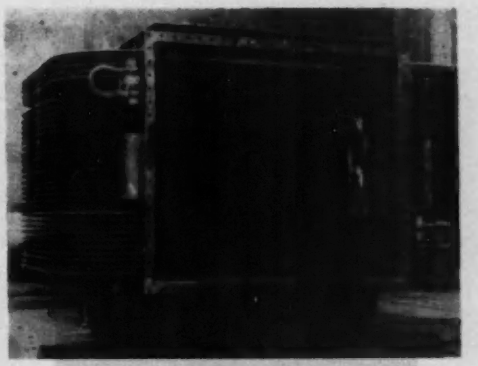

Fig. 18

having a ¼ in. thick stainless steel inner vessel with a ¼ in. thick mild steel jacket, the whole thing being designed for 30 lb. working pressure in the jacket, and to stand a test pressure of 60 lb. per sq.in. hydraulic. Owing to a misunderstanding, the vessel was subjected to a pressure of 150 lb. steam in the jacket after it had left the factory, which caused a complete inward collapse of the inner cylinder. It is interesting to note that although the plate is badly torn, the welds remain perfectly sound, for the tear was in the parent metal, just below the point where the ring for the mild steel jacket attachment was welded to the stainless steel vessel. The whole of the material was recovered and the job tested to the full pressure of 60 lb. per sq.in. in the jacket, and there was no weld failure in any stage of the collapse or the repair. All the stainless steel portions were softened and descaled prior to re-assembling and welding.

It was obvious that, in order to set about this job, the jacket had to be cut away from the inner stainless steel body, and Fig. 23 is a close-up of the inside, with the top cover removed, before dismantling, while in Fig. 24 we have the jacket after removal from the supporting curb, with the inner vessel beside it. One of the main problems in the reclamation of this vessel was to remove the tucks or sharp corners made in the inner vessel, particularly in the dished and flanged end, so that it could be salved. There

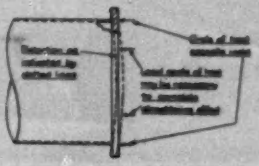

Fig. 19

was only one way in which this could be done, and this was to remove the end plate from the body, accomplished by grinding out the weld by means of a portable grinder, and taking the end plate right away. It was necessary to remove the bottom connexion in a similar manner from the end plate. The body was then placed in a hydraulic angle bending press, and the tucks were carefully and slowly smoothed out by local application of pressure from the hydraulic press.

Pressure was first carefully applied to the more severe spots, which were worked out gradually by rotating the cylinder in the press. After the worst of the tucks had been taken out in the press, the cylinder was placed in the bending rolls. The next problem was to get the end re-formed, and this was done by taking out the worst places by the application of a hammer on a block, and when all possibility of any folding over in the press had been eliminated, the end was then put into the press and emerged as if completely new.

The excellent shape that had been produced out of the mess shown in the previous figures may be judged from Fig. 25, showing the vessel when reassembled with its cover, stirring gear, etc., fitted and ready for despatch to the customer.

Fig. 20

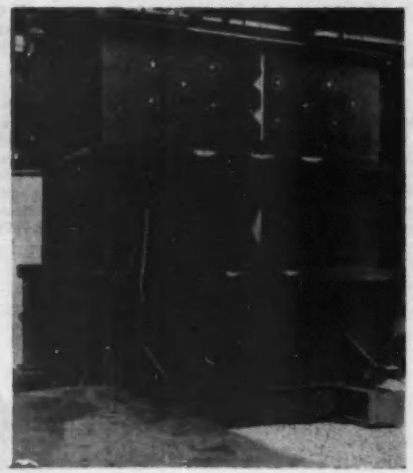

Fig. 21

And a Storage Tank Collapsed

Another job which required rectifying after, as we say in Yorkshire, "it had happened an accident," was an ordinary 32 ft. long × 9 ft. diameter storage tank, which, owing to a mistake during operation, was subjected to a very high vacuum. I have already given you the overall sizes. The tank was made from ¼ in. thick plate and crumpled up completely, as demonstrated in Fig. 26, a picture of the tank coming into the factory on the lorry the welds have been whitened to show their location. The shape into which the tank had been sucked on the top was very curious, and Fig. 27 shows what was, perhaps, the worst part of the trouble, the somewhat sharp fold put into the plate, which

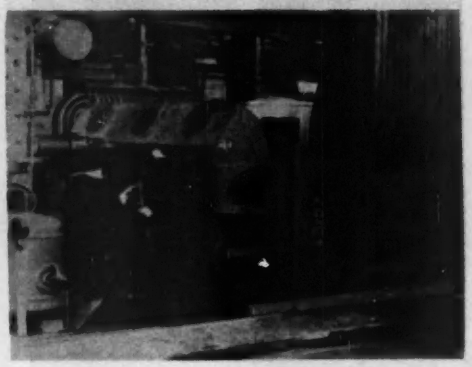

Fig. 22

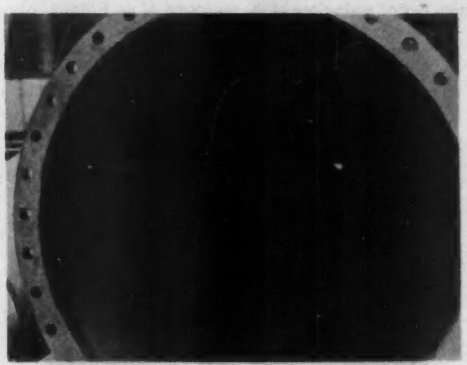

Fig. 23

proved to be the most difficult part of the job to eradicate. It is a very significant fact that, in spite of the internal pressure and movement to which the tank has been subjected, there was no leak in any weld, nor was any weld in the slightest degree torn or broken.

The problem was—how to set about the job. After much thought and discussion, it was decided that an attempt should be made to bring the tank back to its proper shape by means of an application

Fig. 24

Fig. 25

of internal pressure. Since the tank was only of ¼ in. thick plate and the test pressure was only 10 lb. per sq.in., it was obvious that a very high pressure could not be applied to this end. The worst place at the position of the fold, which is indicated in Fig. 27, was a slight tear in the plate itself, and it was obviously impossible to apply any internal pressure until this was sealed up. The tear in the plate was, therefore, welded up as a temporary measure. Water was run into it and the air was vented as far as possible from the various buckles by means of turning. It was, however, impossible to get the water level much above the tear prior to the breakage of the weld. The sharp knuckles undoubtedly had to be eased, and this was done locally by careful application of a hammer and a flattener. The tank was turned in such a position that the weight of the water inside accelerated the progress to some degree. The overall length of the top of the tank then showed an increase of approximately 3 in. A butt strap, somewhat thinner than the plate, that is to say, ¼ in. thick × 2 in. wide, was then welded over the tear, thus allowing the tank to be completely filled with water for the first time, and then a pressure of 3 lb. per sq.in. was obtained. The process of turning the tank, and

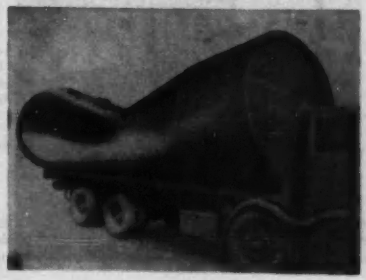

Fig. 26

Fig. 27

easing the various sharp outward knuckles with a hammer and flattener, was continued, until finally the ¼ in. thick butt strap over the tear weld broke through the centre. In the meantime, considerable change had taken place in the shape of the tank. The overall length of the top had now increased by 13 in. The patch over the tear was subsequently replaced by another one a little thicker, this time 3/16 in., and after filling up with water, a pressure between 8 to 10 lb. per sq.in. was maintained. This pressure, together with application of the hammer and flattener in the strategic places, now shaped the tank so that internal work could be effected. The inner knuckles were then eased and further pressure applied. The tear was entirely removed by cutting out a patch of plate 2 ft. 3 in. wide and welding in a new piece. The tank was afterwards brought to its correct cylindrical shape and length by gradual working with the hammer and flattener, and also by the application of the water pressure. Throughout all

these operations the water pressure was applied by means of a compressed air-operated water pump. This pump can be set to maintain a specific predetermined pressure automatically. The use of this piece of apparatus proved of the greatest assistance on this job. Finally, the tank was tested to a pressure of 20 lb. per sq.in., and was absolutely tight all over, and, apart from the patch which had to be welded-in to cover the part which was torn,

Fig. 28

all the welds stood the entirely treatment, and were absolutely tight at the end.

The finished tank on the lorry, ready to leave the factory after the straightening process, is shown in Fig. 28.

Forge Welding History

In conclusion, to delve into a little history, Fig. 29 shows a picture of a hot water boiler, which was made just before the beginning of the first World War in 1914, and which was entirely forge-welded in the fire. The welds are indicated by the slightly darkened line shown around the top of the boiler, and also appear in the stoking hole at the bottom. The whole of the work was lined up by eye during the forging. The boiler may be subjected to checking with a straight edge on all its faces, and, believe me, it is absolutely square and sound and is indeed a wonderful example of the craft of those days. Problems of distortion obviously did not arise; any irregularities were taken out by the hammer whilst the plate itself was red hot from the forging fire.

We have travelled far since those days, and the development of welding has been extensive, while the enormous amount of scientific research which has been put into the process is gradually simplifying it more and more. Modern production methods are tending to specialise the skill of the operators into very narrow

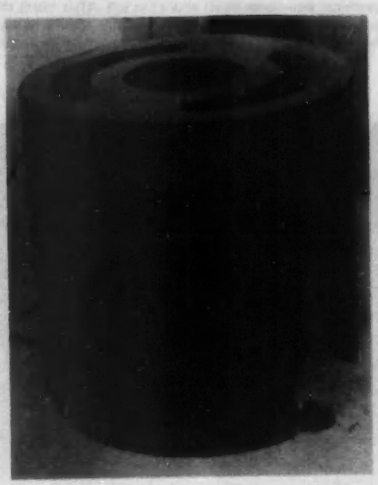

Fig. 29

lines. Personally, I feel that we can all learn much from the craftsmanship of the operators, as indicated in this picture, which even as recently as 1914 was accomplished by methods which would, to-day, be proclaimed as primitive.

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Exhibitions.—The dates of the next Engineering, Marine and Welding Exhibition to be held at Olympia have now been announced as 3-17 September, 1953. The Institute has accepted an invitation to give its patronage as in the past.

The 5th Liège National Fair will be held from 25 April to 10 May next and will again include sections of welding interest.

The American Welding Society is holding a National Spring Technical Meeting at the Shamrock Hotel, Houston, Texas, from 16 to 19 June, 1953, accompanied by a four-day welding and allied industries exposition.

Instruments for Radio Isotope Applications.—The Scientific Instrument Manufacturers' Association of 20, Queen Anne Street, London, W.1, has issued a second edition of its useful list of Instruments and Accessories for Radio Isotope Applications, giving the names of the British manufacturers, arranged under the different types of instrument produced. Copies are obtainable from the Association post free.

A.C. ARGONARC WELDING AT LESS THAN 50 V r.m.s. OPEN CIRCUIT

By J. C. NEEDHAM, B.Sc.(Eng).,* and L. H. ORTON, Ph.D., F.Inst.P.*

Knowledge of the re-ignition characteristics of the alternating current argonarc, revealed by cathode ray oscillographic analysis and dealt with in two earlier reports, is here applied to the development of an electronic unit (British Patent Application No. 20032/50) with considerable practical significance in the field of argonarc welding.

This unit, referred to as a surge injector unit, injects into the welding circuit an automatically timed surge with characteristics matched to the re-ignition requirements of the argonarc. This new development permits a major reduction in open circuit voltage required for argonarc welding, voltages below 50 V r.m.s. for all types of transformer being adequate. Also it substantially eliminates the nuisance of radio interference associated with the use of conventional high frequency spark oscillator equipment. The unit is robust, simple to construct, and can, if required, be arranged to spark-start the arc from cold if touch starting is impracticable.

Use of the unit under optimum conditions enabled the welding of aluminium to be carried out at 30 V r.m.s. open circuit.

(1) INTRODUCTION

In an alternating current arc the gap tends to deionize as the current falls to zero. In general, following current zero, a re-ignition voltage, which is greater than the normal arcing voltage, is required to re-establish the arc in the succeeding half cycle. The problem of arc maintenance reduces to the current and voltage required by the arc at any instant, and the ability of the power circuit to provide them. Satisfactory re-ignition directly affects the so-called "stability" of the arc.

In alternating current welding an inductive circuit, as in Fig. 1 (*a*), is used to facilitate re-ignition of the arc. The current then lags the open-circuit voltage, as illustrated in Fig. 1 (*b*), and an appreciable open-circuit voltage is available to re-ignite the arc at current zero.

Various types of alternating current welding arc are considered to be "easy" or "difficult" to maintain, depending on the degree of electrical stability existent. Apart from the conditions to be satisfied in order to maintain an arc once established, the higher open-circuit voltages required by the more difficult welding arcs imply that their re-ignition voltages are higher. The form of the re-ignition varies for different arcs both in voltage magnitude and wave shape, as shown diagrammatically in Fig. 2. For the "easiest" case, Fig. 2 (*a*), the voltage between the electrode and plate at zero current rises towards open circuit, but hardly exceeds the subsequent arcing voltage. The arc gap has remained so heavily ionized or conducting that it is difficult to distinguish between the re-ignition and arcing stages. Such welding arcs can readily be run at low open-circuit voltages (say, 45 V r.m.s.) without any auxiliary device to assist re-ignition.

The next case, illustrated in Fig. 2 (*b*), has a distinct re-ignition voltage peak following current zero. The arc gap has remained fairly conducting, since the gap voltage does not rise to the full open-circuit value before breaking down to arcing conditions. The re-ignition stage is distinct from the arc stage to which it collapses after sufficient current has been re-established in the gap. Higher open-circuit voltages are here needed (e.g. 70 to 95 V r.m.s.) to accommodate the re-ignition stage and to feed an increasing current into the gap.

Fig. 2 (*c*) illustrates the case where, on extinction of the arc at current zero, the gap voltage rises very rapidly to the open-circuit voltage. If this transient voltage rise is adequate it will break down the gap and lead to the formation of a new arc. This diagram illustrates argonarcs in general, in which the reverse polarity arc (cathode on plate) requires a high re-ignition voltage and the straight polarity arc (cathode on tungsten) readily re-ignites. The

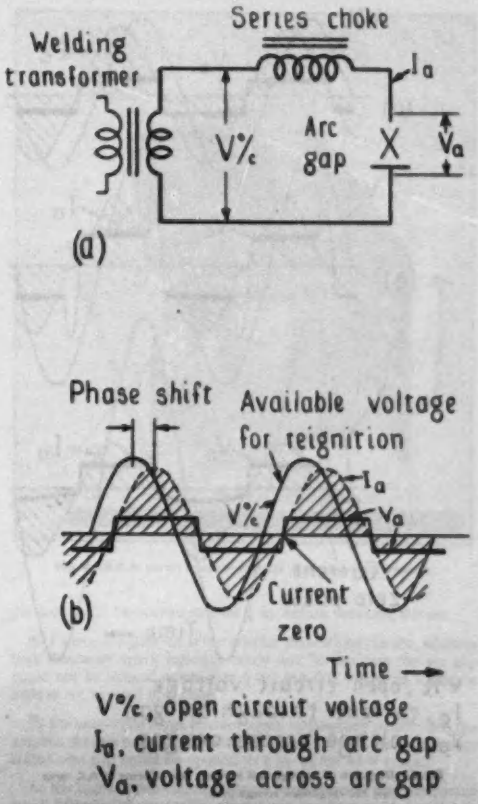

Fig. 1.—Basic A.C. welding circuit and current-voltage relationship.

* Electrical Research Association. The paper is based on E.R.A. report Ref. Z/T 87.

required open-circuit voltage for self-re-ignition of the arc may exceed 150 V r.m.s. for argonarcs, according to plate material (Orton and Needham, 1951) and circuit transients.

If, for reasons of economy and safety, the open-circuit voltage is limited to less than that required to self-re-ignite the arc, then some auxiliary device for arc re-ignition is needed. One method in current use for argonarcs is the injection across the arc gap of high frequency sparks which serve to break down the gap and so re-establish the arc. A major disadvantage of high frequency spark injection, however, is the generation of severe radio interference. Further, although the sparks can break down the gap, an arc may not be finally formed, because of unsatisfactory transition stages between the momentary spark and the power current follow from the welding circuit (Orton and Needham, 1951—see Section 6.3).

This paper deals with an alternative method for alternating current arc re-ignition, in which a cyclically timed surge is superimposed on the power welding circuit, to simulate a circuit of higher voltage. This method is free from difficulties associated with conventional spark injection, and permits the power circuit voltage for argonarcs to be lowered to less than 50 V r.m.s. for any type of welding transformer.

(2) PRINCIPLES OF A SURGE INJECTOR FOR ARC MAINTENANCE

If a given alternating current arc requires a high open-circuit voltage solely for the re-ignition stage, then a lower voltage would be adequate to maintain the arc once it was struck in any one half cycle. The required high voltage power circuit could in principle be replaced by a low voltage heavy current circuit for the main arc, together with a higher voltage low current auxiliary circuit for the re-ignition stage.

Owing to their relative impedance, the two sources must not be permanently joined together, but connected across the arc gap as required. Thus, some switching device, either electro-mechanical or electronic, is needed, and one which is operated according to the arc conditions, as shown diagrammatically in Fig. 3 (*a*). The auxiliary source must, in this case, be able to establish its voltage across the low impedance power source, and for this a precharged capacitor is suitable.

Parameters which may be used for correctly timing the switch include the occurrence of low or zero current or the rise in gap voltage towards open circuit.

The main power circuit rapidly discharges the precharged capacitor after it is connected to the circuit. The voltage apparent

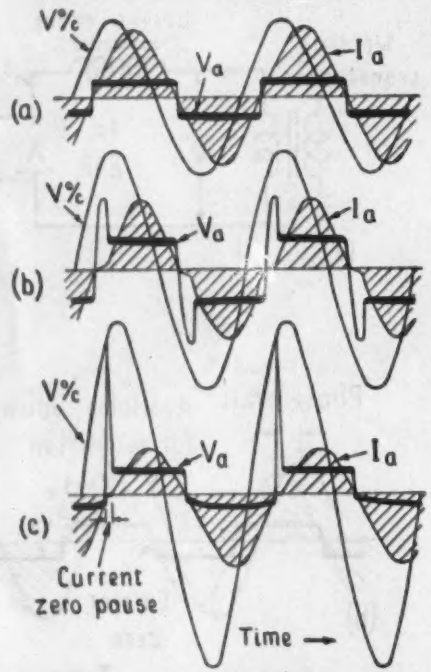

Fig. 2.—Diagram of voltage and current wave-forms in A.C. arcs
(a) No re-ignition voltage peak.
(b) Re-ignition voltage peak.
(c) Re-ignition voltage for reverse polarity as in argonarc.

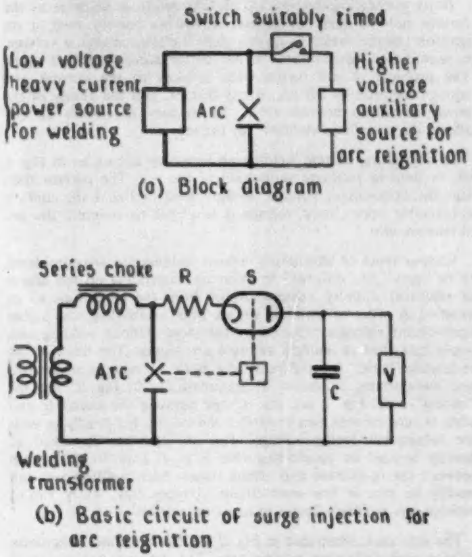

Fig. 3.—A.C. arc re-ignition by auxiliary source.

across the arc gap thus suddenly rises and rapidly falls. This surge is of the same polarity as the arc to be re-ignited and must be at least as great as the arc re-ignition voltage.

When the gap breaks down from the applied surge, the gap voltage suddenly falls from the breakdown value to about the arc value, and the capacitor continues to discharge, mainly into the arc, until the switch is opened. This discharge current greatly aids arc formation, as it provides a suitable current pulse from which the low voltage power source can take over and deliver a half cycle of power. A small resistance in the capacitance discharge circuit critically damps the discharge current to avoid reversing the arc polarity even momentarily.

The essentials of such an auxiliary source for alternating current arc re-ignition are thus, as shown in Fig. 3 (*b*), a low power source

(V) for charging a capacitor (C), a switch (S) for connecting the charged capacitor to the arc or main power circuit, a timing device (T) to operate the switch at the desired instant to re-ignite the arc, and a small resistor (R) to control the discharge current of the capacitor into the arc after the applied voltage surge has broken down the gap.

A surge injecting device working on the above principles is relatively simple to construct, as may be seen in Fig. 4, which is a photograph of a simple surge injector unit.

(3) THE SURGE INJECTOR FOR A.C. ARGONARCS

(3.1) The Argonarc Process for Welding Light Alloys

The term "argonarc" here refers to a welding process in which the arc is drawn between a tungsten rod, or one of like material, and, say, an aluminium work-plate, in a surrounding atmosphere of inert gas, usually argon. As already mentioned, the arc re-ignites readily and at low voltage when the hot rod is negative, but extinguishes and requires a high re-ignition voltage when the plate is negative (see Fig. 2 (*c*)). When the arc is maintained by a high open-circuit voltage alone, the reverse polarity breakdown or arc re-ignition voltage is about 150 V for Al-5 per cent. Mg plate, 200 V for Al, and 300 V for Cu.

Such voltages are clearly inadequate to strike an arc across a cold gap, so that some form of spark initiation is required, is touch-starting is to be avoided. Likewise the surge injector unit for arc maintenance will be unable to strike the arc across the cold gap without touch-starting. The maintaining of an arc and its spark-starting from cold using the surge injector are dealt with separately below.

(3.2) Argonarc Maintenance

As explained above, surges of positive polarity only are required every 1/50th second and timed to occur immediately after the end of each straight polarity half cycle. The surge capacitor (see Fig. 4) is cyclically charged from a mains transformer-rectifier source to about 300 V and connected to the arc by the surge injecting valve (in this case a cold cathode gas-filled tetrode). The operation of this valve is timed by a triode which is controlled by the voltage across the arc gap. When the arc extinguishes at the end of a straight polarity half cycle and the voltage across the gap rises towards the open-circuit voltage, the triode valve trips the electronic switch. The capacitance surge is thus automatically injected within about 20 micro-seconds of arc extinction. The power circuit then delivers a half cycle of heavy current into the newly formed reverse polarity arc. This cycle of events is regularly repeated.

This simple surge injector unit is connected in parallel with the welding leads and any type of welding transformer which will supply the current can be used. Since the re-ignition of the arc is accomplished by the injected surge, only a low voltage welding transformer is required.

(3.3) Argonarc Starting

The typical commercial high frequency spark injector unit is not adequate for starting or maintaining the argonarc at very low open-circuit voltages. The surge injector as described above is suitable for argonarc maintenance. If it is combined with a simultaneous spark it also permits spark starting at low voltage, because, following spark breakdown of the gap, the surge injector provides the necessary current pulse until the power circuit takes over. The normal surge can be converted into a high voltage spark by a step-up transformer.

The photograph (Fig. 5) shows a composite surge injector unit which produces a spark and surge simultaneously by having the primary of a car ignition coil in series with the surge injection circuit. The spark is correctly timed for optimum arc initiation by means of the surge timing circuit. After the arc has been initiated by the spark the unit automatically returns by means of a relay to surge injection alone, by which the arc continues to be maintained.

4) EXPERIMENTAL RESULTS

The open-circuit voltage required to run a given argonarc is here used as a criterion for comparison of the surge injector with other methods of maintaining the arc. In each case the argonarc was struck between a tungsten rod and a scratch-brushed commercially pure aluminium plate and the current adjusted to about 100 A r.m.s. The power source was a leakage reactance type transformer as normally used for ferrous welding, and no series capacitor was added, so that the direct current component was not suppressed.

150 *V r.m.s.*—At about this voltage and above the arc required no auxiliary means for its maintenance, *i.e.* it self-re-ignited from the high open-circuit voltage alone. The arc gap could be opened to over $\frac{1}{2}$ in. before breaking the arc.

100 *V r.m.s.*—Arc maintenance was unsatisfactory, i.e. it extinguished or completely rectified unless well phased high frequency spark injection was added (Orton, Needham and Cole, 1950). (With liberally designed transformers and chokes the arc is self-maintaining at this voltage, because of better transient characteristics of the power supply).

50 *V r.m.s.*—Arc maintenance was not satisfactory, even with well-phased high frequency spark injection alone, as many reverse polarity half-cycles completely rectified or were ignited late in the half cycle.

With the surge injector alone the arc was fully maintained and

Fig. 4.—S.R.A. surge injector unit for argonarc maintenance.

the gap could be opened to over $\frac{1}{2}$ in. before breaking the arc.

40 *V r.m.s.*—Again the surge injector maintained the arc, whereas high frequency spark injection could not. In this case the arc gap could not be opened much over $\frac{1}{8}$ in., but this still gives adequate reserve for manual operation.

30 *V r.m.s.*—The surge injector again successfully maintained the arc, but the gap had to be kept rather small. (With a series capacitor added, the gap could be opened to $\frac{1}{2}$ in. as for 40 V r.m.s.)

At the higher open-circuit voltages, conventional high frequency spark injection alone readily started the arc from cold, but it was unsatisfactory at low open-circuit voltages. At 50 V r.m.s. and

similarly at 40 V r.m.s. open-circuit, however, the composite spark and surge injector unit successfully started the arc within about 0·2 second, then reverting to surge injection alone for arc maintenance. At the lowest voltage of 30 V r.m.s. the spark starting with the composite unit was slow, some few seconds elapsing before the arc was fully established.

The argonarc on copper has a higher re-ignition voltage than on aluminium, and 150 V r.m.s. open-circuit with high frequency

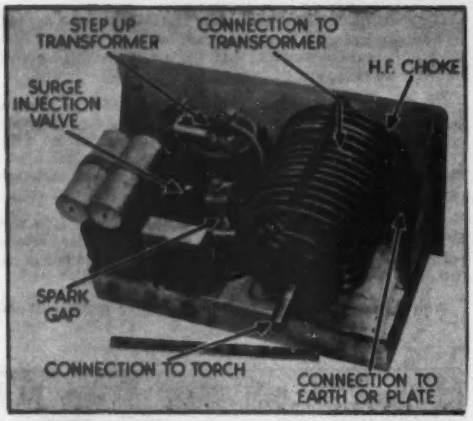

Fig. 2.—B.R.A. surge injector unit incorporating spark starting of argonarc

sparks alone was too low for arc maintenance. A stable arc was, however, surge-maintained at about 50 V r.m.s. and the gap could be drawn to over ½ in. before breaking the arc. The argonarc is also readily surge-maintained on materials having a lower arc re-ignition voltage than aluminium.

(5) DISCUSSION

Both the medium voltage non-oscillatory surge and the high voltage high frequency spark will cyclically re-ignite the alternating current argonarc at a lower open-circuit voltage than that necessary for a self-maintaining arc. Although spark injection permits a substantial lowering of voltage, the drop is limited by the failure of the power circuit at low open-circuit voltages to complete the arc re-ignition process even though the momentary spark has broken down the gap (Orton and Needham, 1951).

The injected surge voltage not only breaks down the hot gap but provides an initial current into the arc gap which completes the re-ignition process and the power circuit can then readily follow up the well-formed arc. Thus with cyclic surge injection unusually low open-circuit voltages, such as 30 V r.m.s., can be used, the limitation being the voltage required to maintain the arc at an adequate gap length for the ensuing cycle.

In a typical commercial alternating current fed spark injector unit, the sparks occur in a group each half-cycle, with about ten sparks per group. For optimum arc re-ignition the input to the unit must be so phased with respect to the main power supply that the spark group occurs around the period of zero welding current (Orton, Needham and Cole, 1950). Even so, there is a delay between arc extinction and its subsequent re-ignition by the first available spark, which reduces the reverse polarity current by about 30 per cent. per millisecond delay. Under optimum conditions the average delay or current zero pause is about half a millisecond. Further, as normally only one spark is required to re-ignite the arc, the remainder in the group are unwanted, and merely add to the severe radio interference. As self-re-ignition of the straight polarity half cycle arc readily occurs, all sparks in alternate groups are generally unnecessary.

With the surge injector timing circuit the current zero pause can be reduced to about 20 microseconds, resulting in negligible reduction in the reverse polarity current loop. Phase shift of the current wave, due to the addition say of series capacitors in the welding circuit to block the direct current component, is automatically covered, since the tripping of the unit is based directly on arc extinction. This feature is absent with the usual high frequency spark injection unit.

Although high frequency spark injection permits a substantial reduction in open-circuit voltage, full advantage cannot be taken of this fact because of radio interference effects. To lessen this interference it is common practice to limit the use of spark injection to starting, or for occasional arc re-ignition after an outage, using relatively high open-circuit voltages for arc running. Compared with high frequency sparks the surge injector unit produces negligible radio interference because of the low voltage of the surge and the non-oscillatory form. It can therefore be in continuous operation, thus allowing the open-circuit voltage to be reduced to well below 50 V r.m.s.

Certain types of welding transformer require a higher open-circuit voltage than others to run a self-re-igniting arc, owing to their less satisfactory transient response at cyclic arc extinction. The surge injector maintains the arc at low circuit voltages for all types of welding transformer, since the surge supplies the necessary re-ignition voltage and current in place of the power circuit.

With additional circuitry, the simple surge injector can automatically produce single timed sparks to initiate the arc across a cold gap, so that the advantage of spark starting can be added to those of surge injection for arc maintenance. Radio interference is reduced, as compared with that from the conventional high frequency spark unit, by timing the spark in relation to the arc's requirements and by generating only one spark instead of two groups of sparks per cycle.

The surge injector units are reasonably robust and can be made more so, if desired, by replacing two of the valves by non-thermionic components, leaving only the switch valve, which is of robust construction.

The overall dimensions of the experimental units designed by the Electrical Research Association are 6 in. × 7 in. × 10 in. for the surge injector alone (weight 7 lb.) and 8 in. × 9 in. × 15 in. for the composite unit (weight 29 lb.) including spark starting and high frequency stopper coil. Both take less than 100 W input. In the case of a 200 A argonarc for example, these units respectively replace some 20 kVA of transformer capacity compared with that required for a fully self-maintaining arc, or some 10 kVA transformer capacity, together with the spark oscillator, for a high frequency spark maintained arc.

(6) CONCLUSIONS

1. A detailed oscillographic study of alternating current argonarc re-ignition characteristics has led to the development of a new electronic device for arc maintenance.

2. Argonarc welding at less than 50 V r.m.s. is practicable, using the new auxiliary device for arc maintenance.

3. This new method of arc maintenance is free from the radio interference associated with conventional high frequency spark oscillators.

4. The principle of operation of the arc-maintaining device is the injection of an automatically timed non-oscillatory short-duration surge to provide for the re-ignition characteristics of the arc at current zero, instead of using conventional high frequency injection, or high open-circuit voltage.

5. The injected surge for arc maintenance is of too low a voltage to initiate the arc from cold without touch-starting, but suitable single-timed sparks can be generated from the surge for spark-starting of the arc across a cold gap.

6. In the experimental composite unit constructed, spark-starting of the arc automatically reverts to surge maintenance once the arc is struck. Radio interference for the brief period of starting the arc is less than with a conventional high frequency spark oscillator, as only a single timed spark is generated per cycle.

7. Surge injection can be used for argonarc welding with any

type of low voltage welding transformer, including leakage reactance type ferrous welding transformer).

8. The current zero pause, which results in a loss of current and is associated with the use of a conventional high frequency spark oscillator for arc maintenance, is eliminated by using the timed surge injector unit.

9. The surge injector is simple to construct and can be made sufficiently robust for practical application. Its use effects major economies in both power and equipment.

10. Using the surge injector unit, welding of aluminium has been successfully carried out at voltages as low as 40 V r.m.s. or, with the addition of a series capacitor in the welding circuit, at 30 V r.m.s.

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NOTES FROM THE BRANCHES

East of Scotland Branch.—At its first meeting of this session, the Committee made a presentation of a Ronson table lighter to Mr. R. M. Young, who resigned the Honorary Secretaryship of the Branch in the summer. Mr. Henzell, the Chairman of the Branch, in presenting the gift to Mr. Young, referred to the great services which he had rendered to the Branch during his five years' tenure of the Honorary Secretaryship.

Manchester Branch.—During the discussion of Mr. John W. Day's paper on Welding Developments in the Shipbuilding Industry, which was given on 1 October last, the almost inevitable questions of the failures of the war-time liberty ships and of notch embrittlement of the steel came up and were answered by Mr. Day with figures showing the very small percentage of failures. Mr. Day also expressed great hope for the future use of aluminium and aluminium alloys in the shipbuilding industry.

Tees-side Branch.—Mr. S. M. Reisser, lecturing on Recent Developments in Welded Structures, showed many examples of modern continental railway stations of the welded rib type of construction, the advantages of which over the lattice girder type, so popular in England, he explained. The audience was specially interested in the description of the construction of the British Welding Research Association's Fatigue Testing Laboratory, embodying the plastic design theory.

North London Branch.—The plastic design theory was also mentioned in a lecture by Dr. H. G. Taylor to the Branch at Slough, when dealing with Developments in Welding Research. Dr. Taylor reviewed the work of the B.W.R.A., describing in particular the development of the plastic design theory, stress analysis of welded joints, the work on fatigue problems and the investigation of brittle fractures. Dr. Taylor said that the Association now felt that it fully understood the mechanism of brittle fracture, on which some fine experimental work had been done and a highly original mathematical analysis made by Dr. A. A. Wells. The lecture concluded with some account of the work in hand on the light alloys and on the determination of the causes of hard zone cracking in low alloy high tensile steel.

South London Branch.—In his Chairman's Address, Mr. J. L. Hamilton made some interesting comments on the educational work of the Institute. This, he said, was primarily the concern of the Institute's Education Committee, of which a past President of the Branch, Mr. E. Seymour-Semper, is Chairman. As the speaker saw it, the Committee's greatest difficulties were trying to persuade universities and technical colleges to introduce welding into an already overcrowded curriculum and trying to persuade production welders to take technical instruction. Continuing, Mr. Hamilton said: "I think it might be interesting to look at the possibilities in those two directions by looking at the evolution of another engineering process which has taken place over a much longer period than our own, namely, machining.

"A long time ago, part of a mechanical engineer's course at a university or technical college was machining—actually doing work on lathes and other machines. As more and more science came into the curriculum that practical phase disappeared, and to-day there is not room in a mechanical engineering course for even the theory of machining, yet a proper understanding of that subject requires as much study as, say, welding. It has to be admitted that a knowledge of welding processes can affect design probably more than a knowledge of machining processes, but I cannot see much possibility of welding design occupying more than a superficial part of a mechanical engineering course.

"Now, applying the same comparison of machining to the other cases, there are skilled welders who can operate with gas, arc, argon and other processes and can also set up automatic welding machines in just the same way as a skilled turner can mill, drill, shape, bore and set up capstan and automatic machines. We must face up, however, to the fact that the majority of welders to-day are really the equivalent of capstan operators with day-to-day work of a repetitive nature, in which they may be highly skilled, but in a narrow field which does not require an apprenticeship. So that I think it is fair to ask the question as a comparison, how many capstan operators go to evening classes?

"At the one educational extreme we can, therefore, say that there is not likely to be an adequate opportunity for student engineers to learn much about welding design, and at the other extreme there is only a limited incentive for the specialised, but semi-skilled welder to become fully skilled. I think it is true to say that the progress of the application of welding suffers acutely, as a consequence, from both sources."

Mr. Hamilton went on to outline the work which the Branches and only the Branches could do in inducing young engineers and operative welders to deepen and widen their knowledge of the welding processes by active membership of the Institute.

INSTITUTE MEETINGS

The following is a list of meetings of the Institute and its Branches in January and February, 1953, so far as details are available at the time of going to press:

7 Jan. **Preston Branch**
Questions and discussion evening; Harris Technical College, Preston, 7 p.m.

7 Jan. **Manchester Branch**
"Recent Developments in Argon-arc Welding with special reference to Argonaut," by W. A. Woolcott; Reynolds Hall, College of Technology, Manchester, 7.15 p.m.

8 Jan. **South London Branch**
"Some Experiences in the Metallurgy of Hard Surfacing," by E. Bishop, B.Sc.; Caxton Hall, Westminster, S.W.1, 6.30 p.m.

8 Jan. **South Wales Branch (West Wales)**
"Reminiscences of Transport Salvage in War Time," by J. R. Dobson; Technical College, Swansea.

8 Jan. **North Eastern (Tyneside) Branch**
"Production and Properties of Titanium," by Dr. N. P. Inglis, M.Eng.; Mining Institute, Neville Hall, Newcastle, 7 p.m.

9 Jan. **Birmingham Branch**
Open Discussion on Welding Problems, Design and Practical; James Watt Memorial Institute, York House, Gt. Charles Street, Birmingham, 3, 7 p.m.

9 Jan. **South Western Branch**
"Welding on Gas Turbines," by H. E. Lardge, B.Sc.; Radiant House, Colston Street (Pipe Lane), Bristol, 7 p.m.

12 Jan. **Sheffield Branch**
Annual Dinner.

13 Jan. **Liverpool Branch**
"Continuous Welded Structures, Abbey Works, Port Talbot," by W. S. Atkins, B.Sc., M.I.C.E.; College of Technology, Byrom Street, 7 p.m. Joint meeting with the Inst. of Structural Engineers.

14 Jan. **West of Scotland Branch**
Meeting at The Inst. of Engineers and Shipbuilders; 39, Elmbank Crescent, Glasgow, C.2. Subject not yet announced.

15 Jan. **Leeds Branch**
Annual Dinner at the Guildford Hotel, Leeds.

15 Jan. **Eastern Counties Branch**
"Tubular Structures," by E. McMinn; Lecture Hall, Electric House, Ipswich.

16 Jan. **East of Scotland Branch**
"Welding of Cast Iron by Arc and Gas Welding," by R. D. Berry and D. W. Wright; at Dundee.

19 Jan. **Sheffield Branch**
"Basic Coated Electrodes and their Characteristics," by H. F. Tremlett, A.R.S.M., B.Sc., F.I.M.; Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield, 1, 7.15 p.m.

21 Jan. **Wolverhampton Branch**
"Developments and Trends in Pipe Welding," by Dr. N. A. Tucker and E. Fuchs, M.A., A.M.I. Mech.E.; Victoria Hotel, Victoria Square, Wolverhampton, 7.30 p.m.

22 Jan. **Indian Branch**
"Welded Rigid Frames," by J. B. Coleman.

22 Jan. **North London Branch**
"The Joining of Aluminium and its Alloys," by W. V. Binstead; Regent Street Polytechnic, London, W.1, 7 for 7.30 p.m.

23 Jan. **East of Scotland Branch**
"Organisation for Arc Welding," by D. M. Kerr, A.M.I.M.; 25, Charlotte Square, Edinburgh, 7.30 p.m.

23 Jan. **East Midlands Branch**
"Latent Developments in Resistance Welding Processes," by C. A. Burton; College of Technology and Commerce, Leicester, 7.15 p.m.

24 Jan. **North Eastern (Tyneside) Branch**
Annual Dinner.

26 Jan. **South Wales Branch (East Wales)**
"The World's Largest Dragline," by C. McL. Cameron; South Wales Inst. of Engineers, Park Place, Cardiff.

28 Jan. **Institute of Welding Annual Dinner**; Holborn Restaurant, High Holborn, London, W.C.1, 7.30 for 8 p.m. Dinner Dress.

29 Jan. **Midway Section**
Film on Arc Characteristics by Dr. L. H. Orton; Sun Hotel, Chatham, 7.15 p.m.

4 Feb. **Preston Branch**
"Welding on Gas Turbines," by H. E. Lardge, B.Sc.; Harris Technical College, Preston, 7 p.m.

4 Feb. **Manchester Branch**
"Developments and Trends in Pipe Welding," by Dr. N. A. Tucker and E. Fuchs, M.A., A.M.I.Mech.E.; Reynolds Hall, College of Technology, Manchester, 7.15 p.m.

5 Feb. **North Eastern (Tees-side) Branch**
Open discussion.

5 Feb. **North Eastern (Tyneside) Branch**
"Welding as an Aid to Production," by D. G. Sinfield; Mining Institute, Neville Hall, Newcastle, 7 p.m.

5 Feb. **Eastern Counties Branch**
Meeting at Norwich City College and Art School, St. George Street, Norwich. Subject to be arranged.

6 Feb. **Eastern Counties Branch**
Meeting at The Liberal Club, Headgate, Colchester. Subject to be arranged.

9 Feb. **Sheffield Branch**
"Flame Cutting and Gas Welding," by F. Clark, M.B.E.; Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield, 1, 7.15 p.m.

10 Feb. **Liverpool Branch**
"The Insurance Surveyor and Welding Repairs," by H. L. Sutherst; College of Technology, Byrom Street, 7 p.m.

12 Feb. **South Wales Branch (West Wales)**
"Non-destructive Testing," by T. J. H. Webborn; Technical College, Swansea.

12 Feb. **South London Branch**
"Welding as a Career," by F. Koenigsberger, Dipl.Ing; Place and time to be announced.

13 Feb. **Birmingham Branch**
"Silver Brazing Alloys — their Types, Properties and Uses," by H. R. Brooker; James Watt Memorial Institute, York House, Gt. Charles Street, Birmingham, 3, 7 p.m.

13 Feb. **South Western Branch**
"Inspection and Testing of Welds in Oil Refinery Construction," by J. R. Dobson; Radiant House, Colston Street (Pipe Lane), Bristol, 7 p.m.

17 Feb. **Leeds Branch**
Lecture by a member of B.W.R.A. at Lighting Service Bureau, Aire Street, Leeds.

18 Feb. **INSTITUTE MEETING, Sir William J. Larke Medal paper, Inst. of Civil Engineers, Great George Street, London, S.W.1, 6.30 p.m.**

18 Feb. **West of Scotland Branch**
"Welding Hazards," by C. C. Bates; Inst. of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2.

18 Feb. **Wolverhampton Branch**
"Modern Developments in Automatic Welding," by J. A. Lucey; Victoria Hotel, Victoria Square, Wolverhampton, 7.30 p.m.

(*Continued on page* 168)

Latest Additions to the Library

As a supplement to the Library catalogue, this section of the *Transactions* contains particulars of books and pamphlets added to the Library during the last quarter of 1952. The books, pamphlets and periodicals specified are available on loan to members of the Institute.

Publications preceded by an asterisk are donations to the Library from authors or publishers; those preceded by a dagger are donated by the James F. Lincoln Arc Welding Foundation.

***AMERICAN WELDING SOCIETY**
(A.S.T-52T). Tentative specifications for copper and copper alloy welding rods for use with the oxy-acetylene, carbon-arc and inert-gas metal-arc (non-consumable) welding processes. Publishers: American Welding Society, 33, West 39th Street, New York, 18. Price: 40 cents.

***ANGLO-AMERICAN COUNCIL ON PRODUCTIVITY**
(a) Education for management. Illus. 1951. **(b) Final Report.** Illus. 1952. Publishers: Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1. Price: (a) 4s. 6d.; (b) 3s. 6d.

***ASEAVETS**
Welding research and progress in the ASEA group. Illus. 1952. (Contains the following papers: (1) Spot welding of ferritic chrome steels, by H. Wängsjo; (2) Static and dynamic strength of joints welded with Aseavets deep penetration electrode Z11P; (3) Dimensioning of fillet welds, by S. Lundback; (4) Generators of fabricated design, by S. Zanders; (5) Argon-arc welding steam turbine and jet engine parts, by O. Dirke and E. Nord; (6) Actual problems of the arc welding industry: coordination of the classifications of electrodes and steels, by S. Svantesson.) Publishers: Aseavets, Stockholm, Sweden.

***BRITISH STANDARDS INSTITUTION**
(No. 499 : 1952.) Glossary of terms (with symbols) relating to the welding and cutting of metals. Publishers: British Standards Institution, 24, Victoria Street, London, S.W.1. Price: 21s.

***BRITISH WELDING RESEARCH ASSOCIATION**
Exhibition of researches and equipment, Abington Hall, 23 June, 1952. Publishers: B.W.R.A., 29, Park Crescent, London, W.1.

***FEDERATION OF BRITISH INDUSTRIES**
Training in Britain of engineers from Latin America: report of the British Engineering Training Mission to Latin America. 1952. Publishers: Federation of British Industries, 21, Tothill Street, London, S.W.Z.

***FISHER, C.**
Lead vessels in radioactive work. Illus. 7 pp. (*Reprinted from "Industrial Chemist," 1957, March.*)

FUCHS, E. and BRADLEY, H.
Welding practice. Vol. 2.—Welding of ferrous metals. Illus. 1952. (Written by members of the Welding Panel of Imperial Chemical Industries Ltd. This volume contains sections on: the welding of mild steel by various processes; welding of high tensile low alloy and Cr-Ni austenitic steels and cast iron; weld details for pressure vessels; hard surfacing by welding methods). Publishers: Butterworths Scientific Publications, 4-6, Bell Yard, Temple Bar, London, W.C.2. Price: 22s. 6d.

GREAT BRITAIN.—MINISTRY OF WORKS
Economy of building materials: report by the heads of the Works Directorates of the Service Departments and the Ministry of Works. 1952. Publishers: H.M.S.O., York House, Kingsway, London, W.C.2. Price: 2s.

INSTITUTION OF METALLURGISTS
The joining of metals: lectures delivered at the Institution's Refresher Course, 1951. Illus. 1952. (Contains the following papers: (1) Metallurgical principles of the joining of metals, by H. O'Neill; (2) Metallurgy of the welding of non-ferrous metals, by W. K. B. Marshall; (3) Metallurgy of welding of carbon and low alloy steels, by L. Reeve; (4) Metallurgy of welding of the Cr Ni austenitic steels, by F. H. Keating; (5) Metallurgy of soldering and brazing, by J. C. Chaston; (6) Determination of weldability, by J. B. Ball.) Publishers: Institution of Metallurgists, 4, Grosvenor Gardens, London, S.W.1. Price: 14s.

***INSTITUTION OF STRUCTURAL ENGINEERS**
Year book and list of members, 1952. Publishers: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1. Price: 5s. to non-members.

INTERNATIONAL ASSOCIATION FOR BRIDGE AND STRUCTURAL ENGINEERING
Fourth Congress, Cambridge and London, 1952. Preliminary Publication. 1952. Publishers: International Association for Bridge and Structural Engineering. Price: £5 5s.

***RURAL INDUSTRIES BUREAU**
(1) Arc welding repairs to manganese steel parts: rock crusher jaws, dredger bucket lips, etc. (2) Oxy-acetylene welding of aluminium. (Typed leaflets.) 1952. Publishers: Rural Industries Bureau, 35, Camp Road, Wimbledon, London, S.W.19.

***TILTMAN RESEARCH LABORATORIES LTD.**
A new approach to research in industry. Illus. Publishers: Tiltman Research Laboratories Ltd., Redhill Aerodrome, Surrey.

***UNITED STEEL COMPANIES LTD.**
The recruitment and training of senior staff. Illus. 1952. Publishers: United Steel Companies Ltd., 17, Westbourne Road, Sheffield, 10.

WELDING ENCYCLOPEDIA
13th edition. New York, 1951. (This is a work of reference and is not available on loan. Members are entitled to borrow the 12th edition issued in 1947.) Publishers: McGraw-Hill Publishing Co. Inc., 330, West 42nd Street, New York, 36. Price: £4 4s.

WOHLFEIL, T. A., FRISK, E. E. and SAXMAN, A. B.
Automobile body conditioning. Illus. 1952. Publishers: McGraw-Hill Book Co., 330, West 42nd Street, New York, 18. Price: 3 dollars 60 cents.

TRADE CATALOGUES

A-C WELDING COMPANY LTD.
"Alternarc" multi-characteristic machines, L.V. range of transformer welders. Address: 199, Haughton Road, Darlington.

ASEASVETS
A survey of our products: resistance, projection, seam, butt-seam, butt, and flash-welding machines, electric resistance heating, arc welding sets, electrodes. Address: Stockholm, Sweden.

BRITISH OXYGEN CO. LTD.
Argonarc spot welding process. Illus. 1952. Address: Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

ELECTRIC ARC, INC.
Smith-Dolan system low frequency induction heating: preheating and normalizing for welding. Address: Newark, 8, New Jersey, U.S.A. Representatives: P. W. Holland & Co., 4, Holland Park Mansions, Holland Park Gardens, London, W.14.

EVERETT, EDGCUMBE & CO. LTD.
(1) The cycle grapher. (2) Measurement of welding currents: high speed A.C. impulse ammeter. Address: Colindale Works, Colindeep Lane, Hendon, London, N.W.9.

FLAME HARDENERS LTD.
Flame hardening by the "Shorter Process." Address: Shorter Works, Bailey Lane, Sheffield, 1.

J. & R. FLEMING LTD.
Fleming industrial safety goggles, helmets, respirators, gloves. Address: 146, Clerkenwell Road, London, E.C.1.

FUSARC LTD.
Fusarc mechanised welding production news sheets. Address: Team Valley, Gateshead-on-Tyne, 11.

GOODYEAR TYRE & RUBBER CO. (GREAT BRITAIN) LTD.
Goodyear industrial hose, which includes oxy-acetylene welding hose. Address: Wolverhampton.

HANCOCK & CO. (ENGINEERS) LTD.
Hancoxygen cutting machines. Address: Progress Way, Croydon, Surrey.

HAVELOCK ENGINEERING CO. LTD.
S.M.3 extruding machine: production rate up to 900 ft. per min. The Havelock Type F.M./1 (175 tons) production extruder: average 8-hour output equals 150,000 electrodes. Address: India Works, Havelock Road, Southall, Middlesex.

ILFORD LTD.
Ilford X-ray films and screens for industrial radiography. Address: Ilford, London.

INVICTA ELECTRODES LTD.
The way to arc welding with Invicta electrodes. 4th ed. 1952. Address: Bilston Lane, Willenhall, South Staffs.

JOHNSON & PHILLIPS LTD.
A.C. multi-operator welding equipment. Address: Charlton, London, S.E.7.

JOHNSON METAL CO. LTD.
What advantages does the Micro-Weld offer the wire industry. The Micro-Welder. Address: Clegg's Court, 45, Chapel Street, Salford, 3, Manchester.

KELVIN & HUGHES (INDUSTRIAL) LTD.
Kelvin Hughes supersonic flaw detector. Address: 2, Caxton Street, London, S.W.1.

GEO. W. KING LTD.
Stop welding glare: portable welding screens. Address: Hartford Works, Hitchin, Herts.

KODAK LTD.
Kodak school of industrial and engineering radiography. Kodak gamma radiography equipment assembly. Can industrial radiography help you? Kodak industrial X-ray catalogue. Address: Kingsway, London, W.C.2.

LINCOLN ELECTRIC CO. LTD.
Lincoln weld directory. Illus. 1952. Address: Welwyn Garden City, Herts.

MANCHESTER OIL REFINERY LTD.
Glo-Mor: a new fluorescent ink for crack detection. The fluorescence lamp, model 15: a portable torch unit for the detection of oil seepage and numerous other industrial applications. Address: Twining Road, Trafford Park, Manchester, 17.

MODERN HARDMETALS LTD.
Mohar for extra hardness and abrasion resistance. Mohar for coal cutter picks. Address: Don Road, Attercliffe, Sheffield, 9.

MUNRO & MILLER LTD.
Tubecraft seamless welding fittings. Industrial radiography. Address: Africa House, Kingsway, London, W.C.2.

MUREX LTD.
Thermit Welding. Address: Murex Ltd., Rainham, Essex.

MUREX WELDING PROCESSES LTD.
Murex electrode guide. Welding equipment and accessories. Address: Waltham Cross, Herts.

NEWTON VICTOR LTD.
Raymax industrial X-ray units. Stationary jib crane for use with Raymax industrial X-ray unit. Raymax crystallographic X-ray equipment. Adjustable film-storage bin. X-ray processing room accessories. Address: 15, Cavendish Place, London, W.1.

OXHYCARBON CO. LTD.
Oxhycarbon welding and cutting accessories. McKechnie bronze welding rods. Secator: portable cutting machine. Quicky: portable featherweight cutting machine with heavyweight capacity. Address: 6, Hainthorpe Road, West Norwood, London, S.E.27.

INSTITUTE MEETINGS contd. from p. 166

19 Feb. **Indian Branch**
"Some Practical Welding Problems," by B. N. Mohindra.

20 Feb. **Preston Branch**
"Fabricating for the Electrical Industry," by H. H. Reeve; Technical College, Barrow, 7.30 p.m.

24 Feb. **East Midlands Branch**
"Practical Stud Welding," by C. A. Sayer, A.I.E.E., and A. R. Ainsworth; Victoria Station Hotel, Nottingham, 7.15 p.m.

25 Feb. **South Wales Branch (East Wales)**
"Non-destructive Testing," by T. J. H. Webborn; South Wales Inst. of Engineers, Park Place, Cardiff.

25 Feb. **North London Branch**
General Brains Trust; Chairman, Dr. R. Weck; Mansion House, Portland Place, London, W.1, 7 for 7.30 p.m.

26 Feb. **Medway Section**
"Light Alloy Welding," by D. T. Carter; Sun Hotel, Chatham, 7.15 p.m.

27 Feb. **East of Scotland Branch**
"Recent Developments in Resistance Welding Technique," by C. A. Burton; 25, Charlotte Square, Edinburgh, 7.30 p.m. Joint meeting with Edinburgh Electrical Society.

27 Feb. **South Western Branch**
"Brazing in Production Maintenance," by T. J. Palmer; Westinghouse Brake Co. Ltd., Chippenham, 7.15 p.m.

Abstracts from Recent Welding Literature

(Compiled by J. L. SANDERS)

THIS section of *Transactions* makes no pretension to completeness but is intended only to provide readers with particulars of some of the more interesting papers appearing in recent welding periodicals.

Readers who need a complete survey should consult the *Bibliographical Bulletin for Welding and Allied Processes* published quarterly by the International Institute of Welding. Particulars may be had from the Secretary of the Institute.

Publications mentioned in the lists below are available on loan to members of the Institute and borrowers will facilitate matters if they will quote the appropriate reference number printed beside each entry.

ARC CUTTING

1710. GUYOT, F.

Utilisation du procédé Oxyarc pour le gougeage des racines des soudures bout à bout.

Arcos, 1952, April, pp. 3190-3197

Describes the application of the Oxy-arc cutting process to the fabrication of storage tanks. Welding had to be carried out from both sides of the plate and the Oxy-arc torch was used to cut out the root run prior to re-welding. Details of suitable joint preparation for this technique are given and some advantages over other methods are claimed.

ARC WELDING—In Inert Atmospheres

1711. STILES, F. J. and LANCASTER, J. F.

Argonarc welding of aluminium brewery plant.

Welding & Metal Fab., vol. 20, 1952, Nov., pp. 293-295

Problems associated with the fabrication of aluminium brewery plant are discussed. As an example the replacement of the wooden lining of a fermenting vessel by an argonarc welded aluminium lining is described, and the problems associated with the welding of large sheets from one side only are considered. Details of suitable jigs and welding procedure are given and the cost of welding by this process and by gas welding are compared for this type of work.

BRAZING

1712. ANON.

Aluminium brazing sheet used in radiator studies.

Steel, vol. 131, 1952, July 7, pp. 96-97

An American company has developed a 3-ply aluminium brazing sheet which consists of a core of 3S alloy with a brazing alloy on one face and an Alclad coating on the other. The purpose of this latter coating is to give sacrificial protection to the 3S core, and the composite sheet has been used successfully in experimental radiators for automobiles.

1713. BERTOSSA, R. C.

High-strength vacuum brazing of clad steels.

Welding J., vol. 31, 1952, Oct. supp., p. 441-447

The development of a vacuum brazing process which does not require the use of a flux or special atmosphere and which has been developed for the production of clad steels is described. The base material is carbon steel and the cladding may be stainless steel or nickel and its alloys. Excellent bonding is obtained over large areas and the clad material may be subsequently formed hot.

1714. WIRT, J. R.

Production brazing.

Welding J., vol. 31, 1952, Sept., pp. 759-764

The author describes briefly the principles of the various brazing processes and outlines their application to a number of products. One such product is an aircraft propeller, in which the copper used as the brazing medium is applied by a metal spraying pistol. A useful chart showing the recommended alloy to use with a given material and process is included.

BRONZE WELDING

1715. PALMER, T. J.

Bronze welding—A review of its history, principles, practice and applications.

Sheet Metal Ind., vol. 29, 1952, Oct., pp. 917-923

This article traces briefly the history of bronze welding and then deals in a practical manner with some applications of the process, giving details of joint preparation and welding procedure. Whilst this process has a very wide field of application, there are certain limitations to its use and these are briefly considered.

FINISHING OPERATIONS

1716. ANON.

Vacu-blasting.

Welding & Metal Fab., vol. 20, 1952, Oct., pp. 361-363

This article describes a grit blasting machine for plate preparation which is clean in operation and may be used in close proximity to other workers without risk of injury. It can be used for cleaning plate edges prior to welding or surfaces before metal spraying or painting. In principle the machine consists of a special blast gun through which the abrasive is driven against the surface by compressed air. Surrounding the nozzle is a chamber which is in contact with the plate surface and communicating with a vacuum pump. The abrasive and all dust and scale removed from the surface are sucked back into a receiver where the abrasive is recovered for further use. The metal surface is left clean and bright and it is claimed that weld quality is improved and welding speed increased by employing this unit. Details are given of special installations for cleaning pipe edges, etc.

FLAME-PLATING

1717. ANON.

Flame-plating.

Welding J., vol. 31, 1952, Oct., pp. 945-950

Describes a new hard surfacing process known as "flame-plating" in which the temperature of the base material does not exceed 400 deg. F. during coating. The surfacing material, such as tungsten carbide, can be applied to almost any base metal, including steel, cast iron, aluminium, copper and its alloys, magnesium and titanium. The wear resistance of the surface is at least equal to that of sintered tungsten carbide and the advantages claimed include lower modulus of elasticity and better resistance to impact and thermal shock. As an example of the advantages of this process, a designer may require wear resistance combined with excellent electrical conductivity and this may be obtained by coating a copper member. Preparation for flame plating, finishing procedure and the properties of the coating are outlined.

HEAT TREATMENT

1718. DeGARMO, E. P.

Should pre-heat be substituted for high-temperature stress relief in the codes?

Welding J., vol. 31, 1952, Sept. supp., pp. 393-396

The results of seven independent investigations show that 400 deg. F. preheat is just as effective as 1200 deg. F. stress-relief heat treatment in improving the performance of low-carbon steel weldments, welded with AWS Type E6010 electrodes, for static and impact load conditions. This evidence is sufficient to justify revising the welding codes to permit the substitution of 400 deg. F. preheat for 1200 deg. F. stress relief under these loadings. Such a substitution would permit more extensive use of welding. Preliminary studies with small specimens indicate that preheat may not be quite as effective as stress relieving in the case of fatigue. However, more extensive tests with larger specimens may produce different results and find them to be equivalent. There is need for tests to determine the relative effectiveness of 400 deg. F. preheat and 1200 deg. F. stress relief under stress corrosion conditions.

(Author's Abstract.)

METAL SPRAYING

1719. VANDERPOOL, H.

Prevention of marine corrosion by metallizing systems.

Welding J., vol. 31, 1952, Sept., pp. 791-798

Deals with the principles of the process, its application to corrosion protection work and the use of plastic sealers. Examples of the effectiveness of the metal spraying process are given. In one such example there was no trace of rusting of a zinc sprayed mild steel surface after 15 years immersion in salt water. It is stated in conclusion that the initial cost of metallizing is justified by reduced maintenance during the first 2-4 years service.

RESISTANCE WELDING.—Butt and Flash

1720. OEHLER, I. A.

Titanium alloys flash welded easily.

Steel, vol. 131, 1952, July 14, pp. 84-85

Satisfactory flash butt welds can be produced on conventional hydraulic machines if the titanium is of uniform structure and if the weldment is annealed at 1650 deg. F. immediately after welding. Brief details for welding ¼ in. diameter rod and 2 in. by 5/16 in. bar are given and it is claimed that titanium alloys have been successfully flash butt welded to certain aluminium alloys and carbon steels.

RESISTANCE WELDING.—Plant

1721. SALATIN, J. F. and ETCHISON, O. D.

Maintenance of resistance welders in high-speed assembly lines.

Welding J., vol. 31, 1952, Sept., pp. 799-808

The incorporation of resistance welding machines in a production line demands that special consideration be given to provision for electrode changing, ease of replacement of parts, etc. Standard machines should be used wherever possible and suggestions are given for increasing their efficiency by the addition of such fittings as ejectors and special fixtures. The advantages of the unit method of construction are noted, in which various components such as timers, welding heads, valves, etc., are capable of very quick replacement.

RESISTANCE WELDING.—Spot and Seam

1722. BURTON, C. A.

Spot welding in the construction of the "Comet."

Welding & Metal Fab., vol. 20, 1952, Nov., pp. 384-388

This article covers spot welding technique for the heat treatable light alloys used in the construction of the de Havilland "Comet" airliner. The author deals first with the pre-weld cleaning procedure in which the components are degreased in trichlorethylene vapour, pickled in 1 per cent. sodium fluoride—10 per cent. sulphuric acid solution, cold water washed, pickled in 40 per cent. nitric acid and finally rinsed in cold water. When components cannot be immersed for the above treatment, they are treated with a special paste-etch, the composition of which is given. Components are held together by widely spaced rivets prior to welding, which is carried out with stored energy equipment. Machine setting data are given for a number of material thicknesses and details of the plant, process control and inspection are noted. Examples of typical spot welded sub-assemblies are shown.

SOLDERING

1723. MACINTOSH, R. M.

Technical aspects of soldering practices.

Welding J., vol. 31, 1952, Oct., pp. 881-897

This comprehensive article on soldering deals with the various processes and their associated equipment, the selection of the correct solder and flux for a specific application, surface preparation and cleaning, design and assembly of parts and special techniques for those metals which are difficult to solder. An appendix contains tables for flux and soldering bit size and details of the various American specifications for soldering alloys.

SURFACING

1724. ANON.

Hardsurfacing applied to tools and dies.

Welding News, 1952, Folio 74, pp. 9-12

Describes the pre-heating required for the successful repair by hardsurfacing of worn punches and dies and gives suitable treatments for carbon and alloy tool steels. (M. R.)

TESTING.—All-Weld-Metal

1725. WARREN, D. and STOUT, R. D.

Porosity in mild steel weld metal.

Welding J., vol. 31, 1952, Sept. supp., pp. 405-420

The results of an investigation into the effect of the welding variables, deoxidation practice, weld metal solidification rate, condition of base material and welding atmosphere are reported.

TESTING.—Corrosion

1726. KARNISKY, B., KINELSKI, E. and GRUCA, E.

Corrosion of structural spot welds.

Welding J., vol. 31, 1952, Oct., pp. 903-916

Low alloy structural steel spot welded assemblies frequently fail as a result of corrosion which may seriously shorten expected service life. Laboratory investigations of corrosion phenomena covering a period of four years have yielded much information and it is recommended that weld sealers be employed and that regular maintenance be performed on structures subjected to corrosive conditions. The article is illustrated by micro- and macro-photographs of some of the specimens used in the test.

1727. PHELPS, H. C.

Making the ocean a test tube.

Welding Eng., vol. 37, 1952, Sept., pp. 32-34.

A short article on an American organisation which is investigating the effect of marine corrosion on various materials and weldments and describes some very interesting results of this work. For example, it is found that a brazed joint between metals which are far apart in the electrochemical series is more satisfactory than a threaded connexion.

TESTING.—Ultrasonic methods

1728. ANON.

An ultrasonic flaw detector for non-destructive testing.

Machinery Lloyd, vol. 14, 1952, Sept. 13, pp. 78-80

This article deals in considerable detail with the principles and practical applications of the echo-sounding type of equipment in which inspection is carried out from one side of the work only. Reference is made to the differences in technique required for welded joints and castings, forgings, etc., and the influence of material, material thickness and form, grain size, surface finish, frequency of vibration, etc., are noted.

NEW MEMBERS

The following elections to membership of the Institute were made by Council on 12 November, 1952:

Members.—J. C. Farr, London, W.C.2; M. P. Henzell (transfer from Associate-Member), Edinburgh, 7; W. I. Horton, Sheffield, 10; A. X. Parthenis, B.Eng., A.I.M., A.M.I.E.E. (transfer from Associate-Member), Rugby.

Associate-Members.—H. Downing, Willenhall, Staffs; H. E. Kitson (transfer from Graduate), Willenhall, Staffs; D. W. Marshall, Walsall, Staffs; D. C. Moore, B.Met., M.Sc., Ph.D. (transfer from Graduate), Sutton Coldfield; H. Moore, Brighouse, Yorks; J. E. Smith, Wyrhall, nr. Birmingham.

Companions.—A. Bean, Stockton-on-Tees; R. C. Hesketh-Jones, B.I.L., London, S.W.7; W. Hutchison, Baillieston, Lanarkshire; K. H. Miller, Ashwell, Herts; J. S. Neale, London, N.W.4; F. W. Pinkstone, Newcastle-on-Tyne, 7; S. A. Pritchard, London, S.E.23; W. C. Stampe, London, N.W.3.

Associates.—G. Bull, Herne Bay, Kent; F. E. Burke, London, E.9; D. T. Hughes, London, N.18; G. T. James, London, S.E.17; D. M. Jones (transfer from Student), Norwich, Norfolk; J. Kitto, Oldham, Lancs.; A. E. W. Rodgers, Barnehurst, Kent; J. K. Sanyal, Calcutta, India; J. Thorburn, Tanganyika, E. Africa; R. N. Walters, Guidborough, Yorks; D. Westwood, Forest Hall, Northumberland.

Industrial Corporate Members.—Oxy-Gas Equipment Ltd., Bexleyheath, Kent; Robert Watson & Co. (Constructional Engineers) Ltd., Bolton, Lancs.

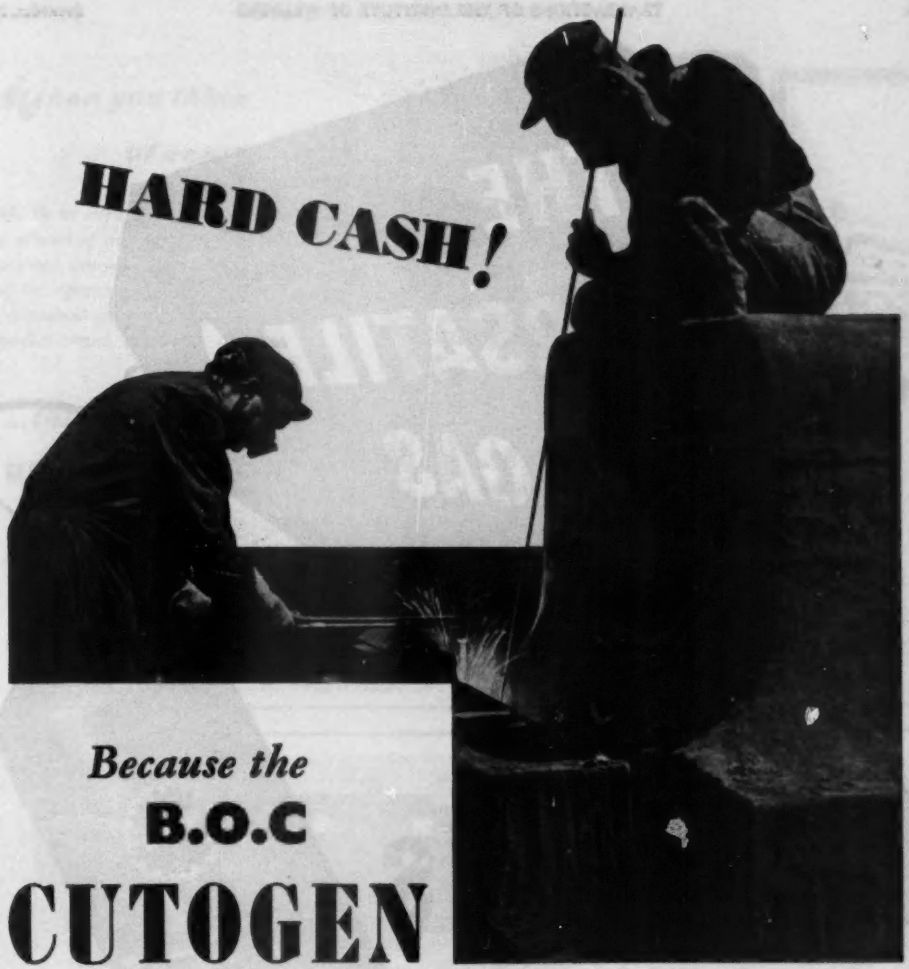
Reinstatements.—C. E. Saunders, Cleveland, Somerset (Associate Member); J. Webb, Toronto, Canada (Associate-Meember).

OBITUARY

We regret to record the death of the following members of the Institute:

T. F. Altham (Member), North London Branch; A. B. Carter (Member), Leeds Branch; F. W. Rowlands (Associate), Birmingham Branch; R. Sarazin (Member), Unattached; T. A. Tindale (Associate) N.E. Tyneside Branch.

HARD CASH!



Because the
B.O.C
CUTOGEN
made it movable!

Cut into movable pieces this old cast iron base immediately became valuable scrap—11 tons of hard cash! The breaking up was quickly and easily done with the B.O.C. ' Cutogen ' hand-cutter.

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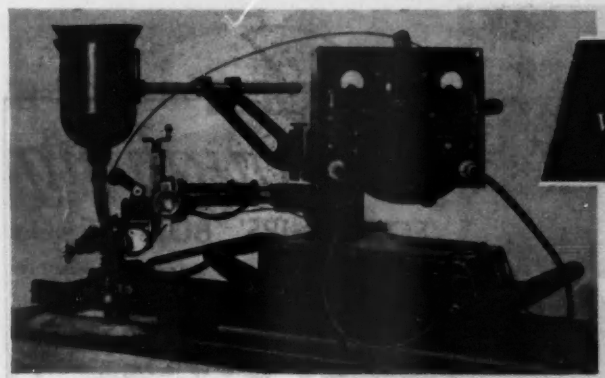

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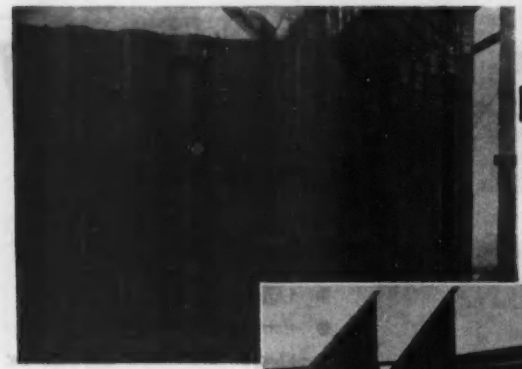

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Photograph by courtesy of Bartram & Sons Ltd.

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Large illustration: TRANSVERSE BULKHEAD IN POSITION
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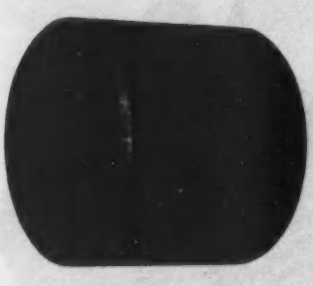

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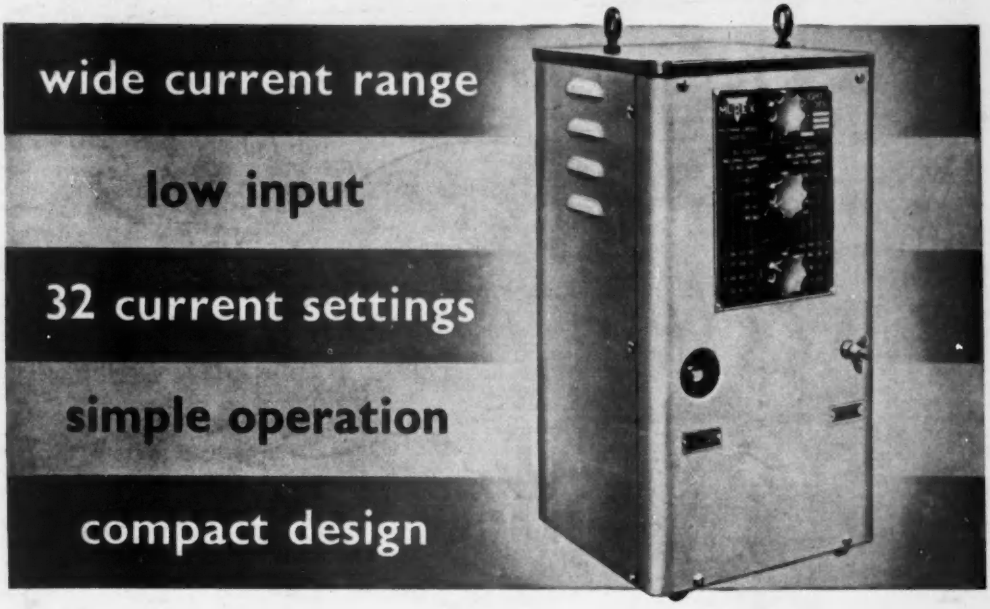

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